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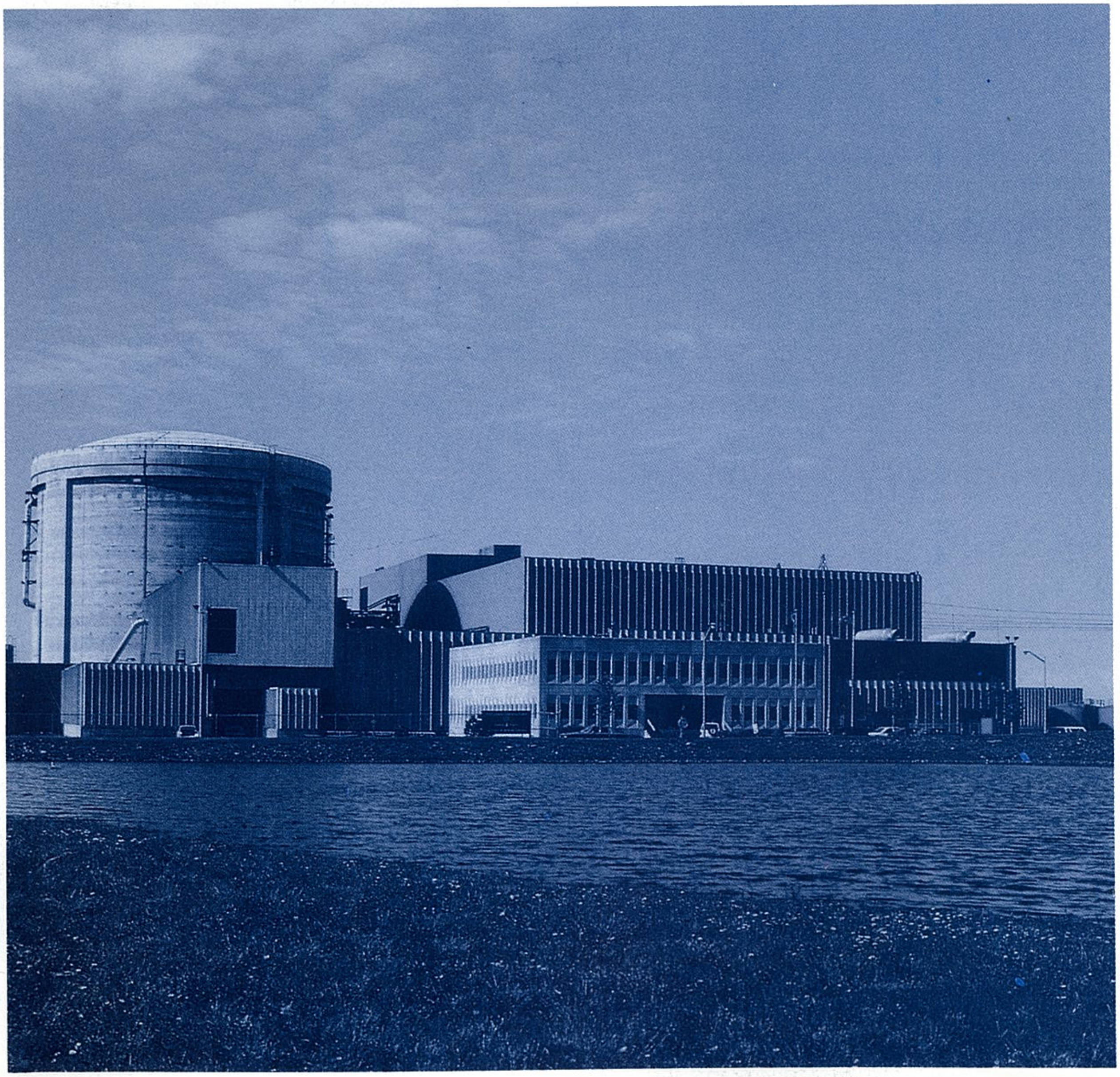

- CNA/CNS Annual Conference
- COG Safety & Licensing Seminar
- 50th Anniversary Paper
- Special technical supplement

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Cover photo

The cover photograph gives a view of the Point Lepreau NGS which, prior to its current shutdown, had the highest lifetime capacity for a CANDU unit and was tied for first place for all nuclear power plants over 500 MW in the world. *(Photo courtesy of NB Power)*

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

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

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ITER – An Opportunity for Canada

ITER is the acronym for the International Thermonuclear Experimental Reactor, the proposed next large fusion machine, which is a joint project of the European Union, Japan, U.S.A., and Russia. Canada is a partner with the EU.

As outlined in the last issue of the *CNS Bulletin,* a group representing many Canadian organizations is proposing that Canada make a determined bid to be the site of this huge project. Despite Canada's junior role in the ITER consortium the proponents believe that Canada has a good chance of being chosen as the location since there is considerable rivalry between the major partners and Canada appears to be everyone's second choice.

The ITER Siting Board and Siting Task Group involve representatives from private industry, universities, manufacturers, labour organizations, government and Ontario Hydro which has offered sites at the Darlington or Bruce nuclear complexes.

The current situation is that these groups have made a formal proposal to the federal government for the financial commitment needed to make a bid to the ITER partnership. Although the commitment is large – estimated at $570 million over 30 years – the return, according to a study by the accounting firm Ernst and Young is more – $11.8 **billion** over the 30 years with $1.6 billion going to the federal government.

Despite that predicted positive return, the current mood of fiscal restraint means that federal politicians will be hesitant. This is where CNS members (and other readers) can help. Letters to the Ministers involved, or to your M.P. (especially if he/she is from the governing party) can be very influential.

The two Ministers primarily involved are Anne McLellan, Minister of Natural Resources and John Manley, Minister of Industry. Mail can be sent to them (postage free !) at the House of Commons, Parliament Buildings, Wellington Street, Ottawa, K1A 0A6.

Their FAX numbers are: McLellan, 613-996-4516;
Manley, 613-995-1534.

For background in composing your letter see the short article in the last issue of the *CNS Bulletin.*

Ontario Hydro Privatization

Finally, the true colours of Ontario Hydro's chairman have been revealed. Almost as soon as the government changed in Toronto Maurice Strong went public with his proposal to "privatize" Ontario Hydro.

Those interested in the future of nuclear technology in Canada or, taking a different perspective, those recognizing the logic and value of nuclear generation of electricity should be worried. Although nuclear generation is competitive in long-term energy costs, is environmentally preferable to coal, oil or hydro, and, unlike natural gas, uses a resource which is abundant and has little other value it is "capital intensive" requiring large initial investment. Private enterprise focuses on short-term return and generally ignores future resource questions.

Those countries with strong, successful, nuclear programs, such as France and Korea, have large, publicly-owned electrical utilities. They are also efficient. France is exporting, at a profit, nuclear generated electricity to its neighbours with privately owned utilities. France's EdF has shown that a publicly owned utility can be run economically while, at the same time, meeting long-term national goals.

If Ontario Hydro is privatized any future for nuclear generation in Canada will disappear. Further the pressures to cut costs (even more) to provide returns to investors will mean that support for on-going programs such as those under COG will be reduced significantly.

The question is broader than the self-interest of those working in the nuclear field. Nuclear energy is the most rationale source of electricity when all factors are taken into account – resource utilization, environmental effects, skilled employment, long-term economics. We need nuclear generation and we need a publicly-owned utility in Ontario.

History Lessons

This summer we celebrate the 50th anniversary of a significant step at the beginning of the Canadian nuclear program – the start-up of ZEEP, our first reactor, on September 5, 1945.

That small project was the first fruit of the remarkable work of the small group of scientists gathered together in the Montreal Laboratory in late 1942. In less than three years, starting with almost no data and experiencing political and management turmoil, they designed the NRX research reactor. NRX, which was built in just three years, became the best research reactor in the world with the highest flux, for many years. Almost as an aside, ZEEP was designed and built in just over six months ! Today it takes that long for a report to get to upper management and back and years for the environmental hearings required for any significant project.

Forty years ago this summer the agreement between AECL, Ontario Hydro and the company then called Canadian General Electric (now GE Canada) was reached and the initial team formed to design NPD, our first CANDU reactor. That group, numbering only a few dozen, designed and oversaw the construction of NPD in just 6 ½ years despite a complete stoppage of work and major change in concept from using a pressure vessel to pressure tubes.

Unfortunately, this summer is also the 50th anniversary of the first test and use of the atomic bomb. The bombing of Hiroshima and Nagasaki with atomic weapons is still a subject of controversy and debate, despite the fact that the "conventional" fire bombing of Tokyo and Kobe, and of Dresden and other cities in Germany, wreaked even more devastation. Those raids, however, involved hundreds of airplanes and thousands of bombs. Hiroshima and Nagaski were dramatic, if tragic demonstrations of the energy in the nucleus.

We still carry the legacy of that first manifestation of nuclear energy. Almost invariably if the word "nuclear" is mentioned people think of a mushroom cloud. Those of us who believe in the benefits of the peaceful use of nuclear energy must be aware of this negative connotation. We do not need to apologize. That first military use is a fact of history. Other products of science have been used for destruction as well as for good. Our focus, our emphasis, must be on the peaceful and beneficial use of nuclear energy (in the broadest sense) – through the production of electricity or heat, in nuclear medicine, for industrial analyses and processes. If we are consistent, conscientious and concerned in all of our endeavours someday society will truly accept us, even if it never learns to love us.

In This Issue

Much of this issue is derived from the 16th Annual Conference of the Canadian Nuclear Society, which was held in June in Saskatoon in conjunction with the 35th Annual Conference of the Canadian Nuclear Association.

Included are three of the plenary talks by leaders of the industry, **Hikmet Akin,** of Uranerz, **Don Anderson,** of Ontario Hydro Nuclear, and **Reid Morden** of AECL, and the paper by **Dr. Agnes Bishop,** president of the Atomic Energy Control Board which, for some inexplicable reason, was relegated to one of the parallel sessions of the CNA.

More in keeping with the focus of the CNS, there is a report by **Alan Wight**, co-chairman of the CNS technical conference, and a selection of abstracts from the four score papers presented.

This technical review is complemented by reports from the CNS Annual General Meeting, ***the*** business meeting of the year for the Society. Included are the report by the outgoing president **Ed Price,** and the talk by incoming president **Jerry Cuttler.** There is also the treasurer's report and financial statement for 1994 so you can see where your money went, or, more correctly, how the efforts of a relatively few organizers not only produced excellent conferences and meetings but also earned most of the income of the Society.

There are two reports on the **Safety and Licensing R and D Seminar** held by the CANDU Owners Group in late May. This was the first year that a representative of the *CNS Bulletin* was invited, previously these have been closed meetings. We found it very enlightening and hope that the brief reports will interest many readers as well.

As a special feature we have a paper especially prepared by **Terry Rummery** and **John McPherson** of AECL for the "Celebration of Canada's Nuclear Heritage," celebrating the 50th anniversary of the start-up of **ZEEP**, our first reactor.

Then there are book reviews and crossword puzzles from our major contributor **Keith Weaver.**

Finally, as a bonus we offer a "technical supplement," the invited paper at the CNS Conference by **Tom Holden,** winner of last year's CNS Innovative Achievement Award, on the applications of neutron diffraction.

Again we thank associate editor Ric Fluke and invite your comments.

Canada's Nuclear Achievement Technical and Economic Perspectives

BY T.E. RUMMERY and J.A. MACPHERSON †

The following paper was prepared for the "Celebration of Canada's Nuclear Heritage" marking the 50th anniversary of the start-up of the ZEEP reactor in 1945.

Introduction

Canada's leading role and eminent accomplishments in nuclear development now span more than half a century. They encompass aspects as diverse as the design and sale of nuclear power reactors and research reactor technology, to the establishment of a corps of scientists, engineers and technologists with the expertise to address a wide scope of important nuclear science issues. The success of a country of modest technical and financial resources, like Canada, in the highly technical and very competitive nuclear field is surprising to many Canadians, and does not fit the usual image we have of ourselves as "drawers of water and hewers of wood". For this reason alone, Canada's nuclear achievement makes an interesting and timely story.

To address the many facets of Canada's nuclear activities over the past 50 years would obviously require space far beyond that available in this paper. We have therefore limited this review to highlights we judge to be the most pertinent and interesting from an historical, technical and economic perspective. We also indicate briefly our view of the future of nuclear power in the overall context of energy needs in a world that is becoming more industrial and increasingly environmentally conscious.

† Terrance E. Rummery and John A. Macpherson are with Atomic Energy of Canada Limited and are Charter members of the CNS.

Dr. Rummery was formerly the President of AECL Research and currently is Science Advisor to the Corporation. In addition to Fellowship in the CNS, Dr. Rummery is a Fellow of the Canadian Academy of Engineering and the Chemical Institute of Canada. In 1993 he was awarded an honorary Doctor of Science degree by Queen's University, and in 1994 the W.B. Lewis medal by the Canadian Nuclear Association, for his distinguished contributions to nuclear science and engineering in Canada.

Mr. Macpherson has served in various capacities as a communications professional and manager during his 23-year career in the nuclear industry. Formerly Director of Public Affairs in AECL Research, he is now Senior Communications Advisor, AECL. He was lead author and editor of *Nuclear Communications*, a recent publication of the International Atomic Energy Agency.

A Brief History

Canada's formal entry into the nuclear age was not enmeshed in technical or political jargon. It was heralded by a simple yet compelling phrase. "Okay, let's go," said C.D. Howe, Minister of Munitions and Supply in the Canadian wartime cabinet, on 1942 August 17. [1]

Howe's decision was the culmination of a year-long discussion with Britain and the United States to move to Canada the heavy water and uranium dioxide research that was then being done at the Cavendish Laboratory in Cambridge, England. By that time, the nuclear story was taking on dimensions of intrigue and adventure worthy of a Hollywood movie. Indeed, 25 years later, Kirk Douglas and Richard Harris portrayed the story of the heroic efforts to remove Norway's heavy water from the grasping hands of Nazi raiders in the film "The Heroes of Telemark". In good screenplay fashion, the predictable "blow-up-the-factory" plot has Douglas and Harris battling with each other more than with the enemy soldiers overrunning Norway. In historical fact, the 185.5 kilograms of Norwegian heavy water – the only heavy water in the world at the time – ultimately found its way to Canada, via France and Britain. It was indeed a saga of adventure.

By the time Canada's own heavy water was first produced in 1943, as a by-product of Cominco's operations in Trail, British Columbia, the AngloCanadian project was under way, and Canada's nuclear story was beginning to unfold. It began in a military context, with the transfer of technology from Britain to Canada, continued with the development of cooperation with the United States, and later moved into a situation where Canada competed in reactor design and sales with its two erstwhile partners. It also moved into a situation where Canada pursued only the peaceful applications of nuclear energy.

As historian Robert Bothwell has observed, "Nuclear fission, nuclear weapons, and nuclear energy are an international phenomenon, and Canada's atomic energy project grew up in a context far beyond its borders." [1] But the context was indigenous as well as international. By the 1940s, Canada's nuclear pedigree was well-established, having begun before the turn of the 20th century when Ernest Rutherford set up a laboratory at McGill University in Montreal for research into the structure of the atom and radioactivity. Rutherford contributed to modern atomic theory with his concept of ion behaviour. "Ions are such jolly little beggars; you can almost see them," he quipped. [2]

In 1931, prospector Gilbert Labine discovered Canada's first uranium deposit at Great Bear Lake in the Northwest Territories. Maclean's magazine reported at the time that "At one stroke the northward thrust of civilization through the Northwest Territories to the borders of the Arctic Sea has been given an impetus and objective." [2] Eventually, Canada became the world's largest uranium producer and exporter.

In 1940, George Laurence, protege of Canada's chief scientist, Chalmers Jack MacKenzie, began experimental work on nuclear fission at the National Research Council laboratories in Ottawa. This work was continued in laboratories established at the University of Montreal as part of the Anglo-Canadian project. It was a favourable environment allowing C.D. Howe, a former professor of engineering and a successful businessman familiar with the management of large projects, to keep his finger on the pulse of an enterprise fraught with technical and intellectual challenge.

An early remarkable achievement of the Canadian nuclear program occurred on 1945 September 5. By then, the Montreal project had moved to the Chalk River Laboratories (CRL). From there, Lew Kowarski, who had followed the prized heavy water on its travels from France to England to Canada, sent a cryptic telegram to Ottawa. It said simply, "Operational condition reached." [3] This understated message referred to the first self-sustaining nuclear chain reaction in the Zero Energy Experimental Pile reactor (ZEEP). The event marked the beginning of a half-century of progressive achievement and universal recognition for the Canadian nuclear industry.

The possible use of nuclear energy for electric power production was discussed in the early years of the nuclear research program, but the first definitive key decision came early in 1953 when C.D. Howe stated in the House of Commons, "Here in Canada we believe that the time has come to undertake the development of atomic power in this country, and discussions are going on as to ways and means of bringing about that development. We feel that the production of power is the concern of those who distribute power, organizations like the Hydro Electric Power Commission of Ontario, or the major privately-owned power companies."[4] Half a century after Rutherford's discoveries, Howe, MacKenzie and Laurence were pushing Canada into 20th century high technology. "Canadians were no barefoot water-boys when atomic science matured into nuclear technology," writes Ray Silver, a journalist and author who has been observing the nuclear scene for more than 40 years.[2]

Howe's conclusion led quickly to another key decision when Atomic Energy of Canada Limited (AECL) agreed to set up a study team, headed up by Harold Smith of Ontario Hydro, to look at a small power reactor. In addition to Ontario Hydro staff, the team had representatives from other utilities, industry and consulting engineers. The specific goal was to have generating stations with excellent safety, environmental, and reliability characteristics, developed and made in Canada, so as to provide an overall benefit to the Canadian community.

W.B. Lewis, an outstanding scientist of world stature, and his colleagues at AECL's Chalk River Laboratories, provided the scientific impetus that the engineers translated into practical plans. Lewis pursued the preservation of neutrons with evangelical intensity. His commitment to neutron economy resulted in low fuel costs for CANDU reactor plants, and this became a significant factor in their success.

In 1987, the centennial of engineering in Canada, the CANDU reactor was ranked as one of the country's top ten engineering achievements. In a commemorative publication,[5] CANDU reactor development was described as follows: "The CANDU (Canada Deuterium Uranium) nuclear reactor is a case where Canada carried through with the development of new technologies created during the war. In 1945, the ZEEP reactor at CRL became the world's first nuclear reactor in operation outside the United States. This was followed in 1947 by NRX, the world's most powerful research reactor, and by the NRU reactor at Chalk River in 1957. These reactors provided the base for the development of fundamental nuclear power technology."

The commemorative document also noted that, "During this same period, Ontario Hydro was looking for new sources of electricity to satisfy the rapidly growing demand in the province. The joint industry-government approach that had proved so successful in Canada in the past was followed. AECL, Canadian utilities and private industry concluded that the CANDU reactor was the route to pursue."

The Present

It is now 40 years since the partnership was formed between Atomic Energy of Canada Limited, Ontario Hydro and Canadian General Electric to build Canada's first nuclear power plant called NPD for Nuclear Power Demonstration. This small station was the prototype of the flagship of the nuclear industry – the CANDU reactor – which occupies a prominent position among world nuclear power reactors for its safety, dependability and performance. More specifically, the outcome was a power system that was the product of the combined forces of creative intelligence, persistent sense of purpose, tenacious pursuit of practical remedies to complex engineering challenges, and innovative solutions to make nuclear power commercially feasible. Outstanding engineering developments made a demanding technology into a reliable, safe, economic and tolerant one that has stood the test of time.

The CANDU reactor has three major features that distinguish it from the two U.S. designs which constitute its major competitors, the PWR [pressurized (light) water reactor] and the BWR [boiling (light) water reactor]. These distinguishing features are:

- its use of indigenous natural uranium as fuel, as opposed to fuel enriched in the fissionable isotope of uranium, 235U;
- the use of pressure tubes rather than a large pressure vessel to hold the fuel; and,
- the use of heavy water, rather than ordinary or light water, as coolant and moderator.

A schematic of the CANDU reactor is shown in Figure 1.

The location of the fuel, pressure tubes and heavy water, which together constitute the heart of the CANDU reactor system, are shown here, along with other major components of the overall generating system, that is, the containment building, the turbine and the generator.

The pressure tube design gives the CANDU reactor another unique advantage: the ability to refuel the reactor without shutting it down. On-power refuelling is a major contributor to the economic competitiveness of a natural uranium reactor. It provides four major advantages:

- it enables the unit to have a high capacity factor which lowers the total unit energy cost;
- it allows for increased burn-up of CANDU fuel and therefore lowers fuelling costs;

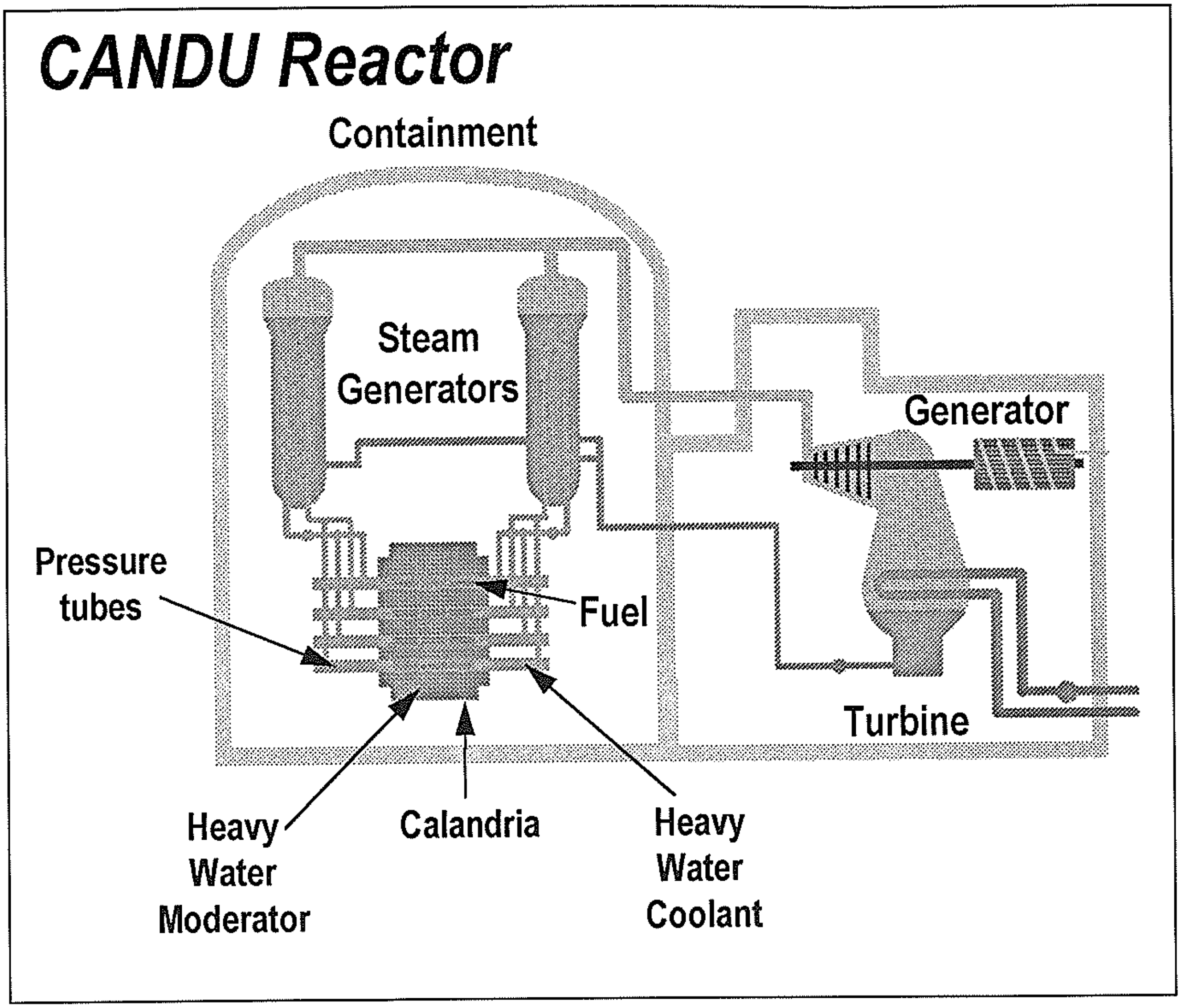

Figure 1: Schematic of the CANDU reactor

- it permits on-power removal of defective fuel; and
- it permits the scheduling of maintenance shutdowns independent of refuelling requirements.

These characteristics, as well as the engineering and operating excellence that has become the CANDU reactor hallmark, have consistently placed CANDU reactor units among the world's best-performing reactors, as shown in the next figure.[6] Of the world's 371 power reactors over 150 MW in generating capacity, six of the top 25 are CANDU reactors.

There are currently 22 CANDU reactors operating in Canada, and one in each of Korea and Argentina. Five more are under construction, three in Korea and two in Romania. In the late 1960s, Canada supplied one reactor to Pakistan and two to India. The latter subsequently built similar reactors without Canadian involvement.

Economic Benefits

The economic benefits flowing to Canada from the development and sale of CANDU reactors have been, and continue to be, significant. A recent study by Ernst & Young,[7] summarized in Figure 3, shows that, among other benefits,

- over the period 1952-1993, an investment of $4.7 billion in funding to AECL resulted in a $23 billion contribution to Canada's GDP;
- foreign exchange savings of $17 billion were realized from 1965-1989, and electricity cost savings in Ontario amounted to $5 billion;
- in 1992, 30,000 people were directly employed in the nuclear industry, and 10,000 indirect jobs were created;
- over 150 private sector suppliers have received business in goods and services. For example, in the period 19891993, this value was $9.4 billion. The distribution of these businesses across Canada is shown in Figure 4.

Another economic benefit of note is that the nuclear industry was only one of two high-technology industries in the period 1990-1993 that had a positive balance of trade, the other being aerospace.[8]

Technology Spin-Offs

As indicated in Figure 3, another economic benefit from Canada's nuclear development has come from technology spin-offs. Among these have been:

Lifetime World Power Reactor Performance to December 31, 1994* from among 371 reactors over 150 MW.

Rank	Country	Unit	Type	Year of First Power	Capacity Factor %†
1	Germany	Emsland	PWR	1988	91.4
2	Canada	Point Lepreau	CANDU	1982	91.4
3	Germany	Neckar 2	PWR	1989	88.8
4	Germany	Grohnde	PWR	1984	88.0
5	Canada	Pickering 8	CANDU	1986	87.9
6	Belgium	Tihange 3	PWR	1985	87.7
7	Canada	Pickering 7	CANDU	1984	87.2
8	Finland	Loviisa 2	PWR	1980	86.7
9	Hungary	Paks 2	PWR	1984	86.1
10	Switzerland	Beznau 2	PWR	1971	85.9
11	Germany	Philippsburg 2	PWR	1984	85.4
12	Hungary	Paks 4	PWR	1987	85.2
13	Hungary	Paks 3	PWR	1986	85.1
14	Canada	Darlington 4	CANDU	1993	84.9
15	Canada	Pickering 6	CANDU	1983	83.9
16	Switzerland	Gösgen	PWR	1979	83.8
17	Germany	Grafenrheinfeld	PWR	1981	83.8
18	Korea	Wolsong 1	CANDU	1982	83.7
19	Finland	TVO 1	BWR	1978	83.3
20	Spain	Almaraz 2	PWR	1983	83.3
21	Spain	Asco 2	PWR	1985	83.2
22	Belgium	Tihange 2	PWR	1982	83.0
23	Finland	Loviisa 1	PWR	1977	82.8
24	Finland	TVO 2	BWR	1980	82.8
25	Hungary	Paks 1	PWR	1982	82.7

the world's top 25 reactors

* Source: *Nuclear Engineering International*

† Capacity Factor = $\frac{\text{(actual electricity generation)}}{\text{(perfect electricity generation)}}$

Figure 2: The World's Top 25 Reactors

- ***the supply of molybdenum-99 (99 Mo) used for medical diagnostic purposes***. Currently, about 80 percent of the world's supply of 99 Mo is produced in AECL's research reactor at CRL and further processed and marketed by Nordion International Inc.;
- ***research reactor designs based on AECL's MAPLE (Multipurpose Applied Physics Lattice Experiment) technology***. The 30 MW HANARO research reactor in Korea, which commenced operation this year, is based on MAPLE technology;
- ***design and supply of linear electron accelerators (IMPELA) for radiation processing applications in medical sterilization and materials properties enhancement***. Two IMPELA units were recently sold into a market that is projected to grow significantly over the next few years;
- ***eddy current probes for non-destructive examination of steam generator tubing.*** This technology is now used by Westinghouse Nuclear Energy Services under licence to AECL; and
- ***neutron and gamma dosimeters, used for example in under sea and outer space applications***. These detectors are produced and marketed by Bubble Technologies Industries Inc.

Environmental Benefits

The environmental advantages of nuclear power can be categorized in general as two-fold: first, nuclear electricity generation entails a process that does not involve chemical combustion of fossil fuels that produces carbon dioxide (CO_2), a major contributor to what is known as the "Greenhouse Effect",[9] and other atmospheric pollutants such as sulphur dioxide, nitrogen oxides, carbon monoxide and particulates. Second, nuclear power entails the practice of containment rather than dispersal of the wastes produced. Some representative data, contrasting a nuclear plant with a coal-fired plant, are given in Figure 5.[10]

Concern has been growing steadily about the extent to which the greenhouse effect is resulting in global warming. It is estimated that CO_2 today accounts for

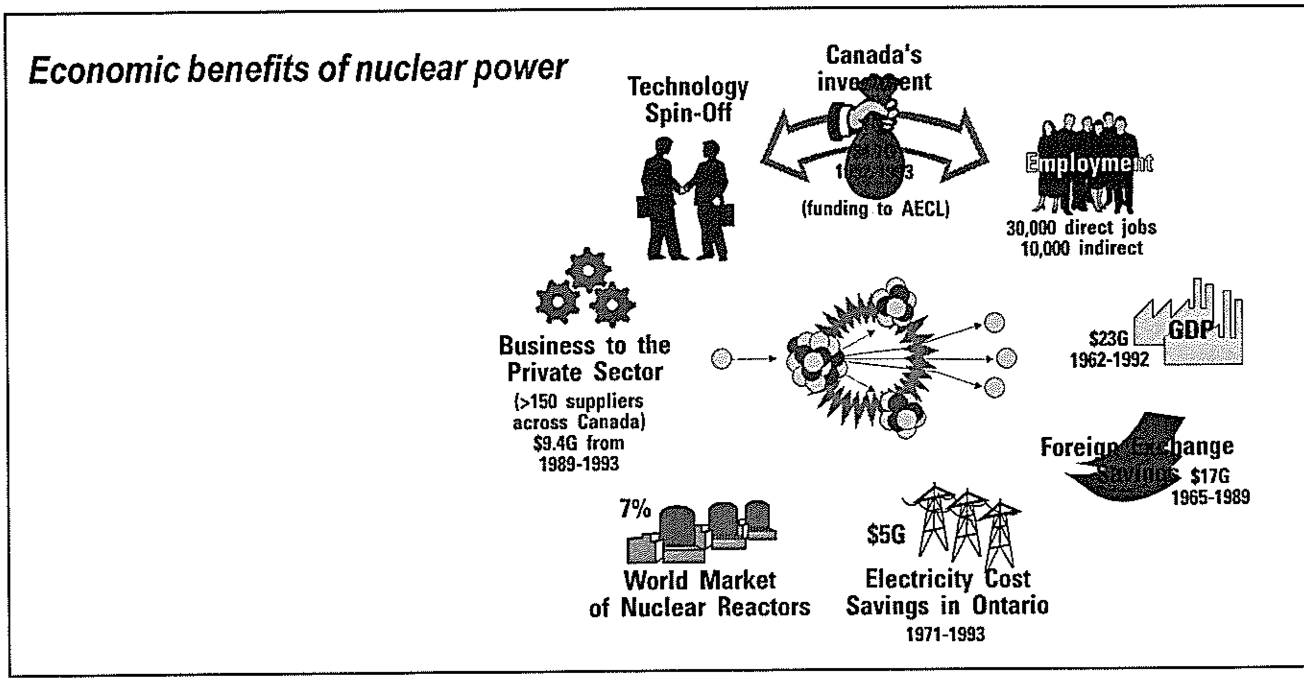

Figure 3: Economic benefits of nuclear power

more than 60 percent of the greenhouse perturbation.[9] Most current climate models suggest that when the concentration of CO_2 in the atmosphere reaches twice preindustrial levels (approximately 1.2 trillion tonnes of carbon versus about 760 billion tonnes today), the global mean temperature will increase by 1.5 to 4.5C.[11] Temperature increases of this magnitude could result in climatic disruptions such as major storms, droughts, heat waves and flooding of coastal areas. In important food producing areas, large changes could be disastrous.[12]

One can conclude from these data, even recognizing that the consequences of the greenhouse effect (global warming) may not be as dire as now predicted, that avoiding the release of CO_2 to the atmosphere to the maximum extent possible makes prudent environmental and economic sense. The risks of doing otherwise are simply too great. We would note that if nuclear electricity were replaced today by coal burning generation, emissions of CO_2 world-wide would rise by seven percent or two billion tonnes per year.[13] In Canada, nuclear versus coal burning electricity generation by Ontario Hydro, in the period 1971-1990, has obviated the release of 609.5 million tonnes of CO_2 in Ontario.[14] Similarly, avoidance of the production of the other pollutants from fossil fuel burning, noted above, has a significant beneficial effect given that these pollutants affect both human health and vegetation.

The radioactive wastes produced by the nuclear generation of electricity are for the most part retained within the plant. While a small fraction is released (strictly controlled within regulatory-allowed limits), the vast majority of wastes are contained and isolated on site until a decision for final disposal is taken.[15]

Although the technology for disposal of all radioactive waste (low-, intermediate- and high-level) has been or is being developed, it is the last that has required most attention. More than 15 years ago, on behalf of the Canadian government, AECL initiated an extensive research and

Geographic Distribution of Suppliers to the Canadian Nuclear Industry

Location	*No. of Suppliers*	*Percentage*
British Columbia	3	2.0
Alberta	21	13.6
Saskatchewan	4	2.6
Ontario	89	57.8
Quebec	18	11.7
New Brunswick	4	2.6
United States	15	9.7
Total	154	100.0 %

Source: Ernst & Young, "The Economic Effects of the Canadian Nuclear Industry," Oct. 1983.

Figure 4: Geographic Distribution of Suppliers

development (R&D) program for the safe and permanent disposal of nuclear fuel waste (high-level waste).[16] The program has involved many scientific disciplines, including geological and environmental sciences, physics, chemistry, mathematics, metallurgy, engineering and social sciences. Much of the work has been conducted by AECL at its Whiteshell Laboratories in Manitoba, (which include the Underground Research Laboratory), at its Chalk River Laboratories in Ontario, and at several field research areas in the Canadian Shield. Other organizations have also participated in the R&D on disposal, including Ontario Hydro, Natural Resources Canada, Environment Canada, universities and consultants in the private sector. The technical aspects of the program have been continuously reviewed by representatives from learned scientific and engineering societies in Canada. Also, AECL has consulted broadly with members of Canadian society to help ensure that the proposed disposal concept and the way in which it would be implemented are technically sound and represent an acceptable disposal strategy.

The proposed disposal concept entails geological disposal in which the waste is sealed in long-lasting containers emplaced in a disposal vault excavated at a nominal depth of 500 to 1000 metres in plutonic rock of the Canadian Shield. Each container is surrounded with a sealing material, and all excavated openings and exploration boreholes are (eventually) sealed to form a passively safe system. Humans and the natural environment would be protected from contaminants in the waste by multiple barriers: the container, the very low-solubility waste form, the vault seals and the geosphere.

This disposal concept is now being reviewed by a federal Environmental Assessment Panel. Acceptance of the concept would not imply approval of any particular site or facility. If the concept were accepted and implemented, a disposal site would be sought, a facility would be designed specifically for the proposed site, and the potential environmental effects of the facility at the proposed site would be assessed. Concept implementation would occur in stages and would entail a series of decisions about whether and how to proceed.

Nuclear Research and Development

Throughout its history, AECL has maintained a very broad base of scientific and engineering expertise. The relative prominence of the various disciplines has of course evolved over the years as the technology has expanded and matured. In the early period, the various sub-disciplines of physics dominated as reactor concepts were explored and the necessary fundamental data were accumulated. The importance of chemistry in its many manifestations grew over the early period and has continued to grow as the R&D has increasingly focussed on the areas of reactor and steam generator equipment maintainability, and fuel cycle diversification. The life sciences were also important in the earliest period given that health and safety were recognized from the start as critical issues. And the life sciences, particularly radiation biology, have continued in importance as AECL explores the fundamental interactions of radiation with humans and the environment. The environmental sciences have grown considerably in application over more recent years, particularly in conjunction with the waste management program. Throughout, engineering disciplines, particularly mechanical, chemical and electrical, have played vital roles as the basic and applied science has been transformed into operating reality. A survey of the various disciplines, and their area of particular application, is given in Figure 6. A comprehensive technical history of AECL, as seen from its research laboratories, has recently been compiled and will be published in 1996.[17]

AECL also conducts scientific research which, while related to its primary mandate to develop and apply nuclear power technology, and CANDU reactor technology in particular, contributes more directly to the overall understanding of nuclear and related science in general. These R&D activities, which have given AECL the role of Canada's de facto national nuclear laboratory, fall into several categories of which the highest profile are:[18]

(i) heavy-ion physics, primarily through the operation of the Tandem Accelerator Superconducting Cyclotron. This basic nuclear science activity, to investigate the fundamental properties of matter, has kept AECL and Canada at the forefront of nuclear physics research since the 1940s;

(ii) condensed matter science, involving thermal neutron scattering to probe solids and liquids at the level of interatomic and intermolecular interactions. The supply of neutrons from the NRX, and later the NRU, research reactors has allowed AECL researchers, and researchers from other organizations, to compete successfully in this important field for over 40 years. In 1994 the

Nuclear versus Coal-Fired Electricity Generation (1000 MW)

	Coal	*Nuclear*
Fuel (tonnes / year)	**2.5 - 3.0 M**	**125**
Wastes (tonnes / year)	**• Ash 300-700 k** **• CO_2 6 - 7 M** **• SO_2 40-120 k** **• NO_x 20-25 k**	**• Used fuel 125** **• Low- and Intermediate-Level Radioactive Waste 200-600**

Figure 5: Nuclear versus Coal-fired Electricity Generation

Nobel Prize in Physics was awarded to Bertram Brockhouse for his pioneering work in neutron scattering at CRL in the 1950s and early 1960s;

(iii) neutrino physics, through participation in the Sudbury Neutrino Observatory (SNO), an internationally-sponsored project located in a deep mine at Sudbury, Ontario. SNO is intended to measure the properties of neutrinos through the detection of solar neutrino emissions;

(iv) accelerator technology development, for the design and construction of major accelerator facilities. This work has led to a technology spin-off, the IMPELA, as noted earlier; and

(v) radiation applications that exploit AECL's long-standing expertise in radiation chemistry to develop a wide array of industrial applications for radiation, and particularly to support the marketing and sales of the IMPELA accelerator.

The Future

Future developments will concentrate on AECL's flagship product, the CANDU reactor. In the shorter term, these developments will be evolutionary and will be designed to meet emerging utility design and performance requirements by building on the CANDU reactor's unique strengths and by integrating new technologies as they are developed.[19] The proven features of the CANDU reactor that will be retained include:

- horizontal channels (pressure tubes),
- heavy water moderator,
- fuelling flexibility resulting from high neutron economy,
- on-power refuelling,
- simple, low cost fuel bundles, and
- zirconium alloy pressure tubes.

while the high-level goals to be addressed are:

- maintenance of capacity factors greater than 90 percent,
- reduction of capital and operating costs,
- further development and exploitation of fuelling flexibility,
- further enhancement of safe operation (including reduced frequency/consequences of human error), and
- increased level of plant protection.

One of the most important features of the CANDU reactor under active development focuses on its fuel cycle flexibility.[20] As shown schematically in Figure 7, the CANDU reactor's neutron economy permits the use of not only natural uranium (0.7% 235U) but other sources ranging from slightly enriched uranium (1.2% 235U) to used fuel recovered from PWRs.

In the longer term, more dramatic changes in the design of future CANDU reactors, such as the use of more thermodynamically efficient coolants, for example organic liquids, are envisaged. But whatever changes may be pursued through innovative R&D, the goal will remain the same: to maintain and improve the excellent safety, reliability and competitive performance of the CANDU reactor, and to carry its outstanding record into the 21st century.

And what does the future hold for nuclear power? Undoubtedly the intensity of lessons learned from history will help determine the brightness or dimness of future prospects. The dawning of the second half-century of nuclear fission presents a renewed sense of challenge.

Internationally, nuclear energy is on high-level agendas where world-wide issues of economic development, energy supply, environmental protection, safety, health and quality of life are being addressed. The concept of sustainable development is no longer a debating point but a point of departure. And it gives nuclear power an edge over energy sources that do not involve the safe containment and disposal of wastes.

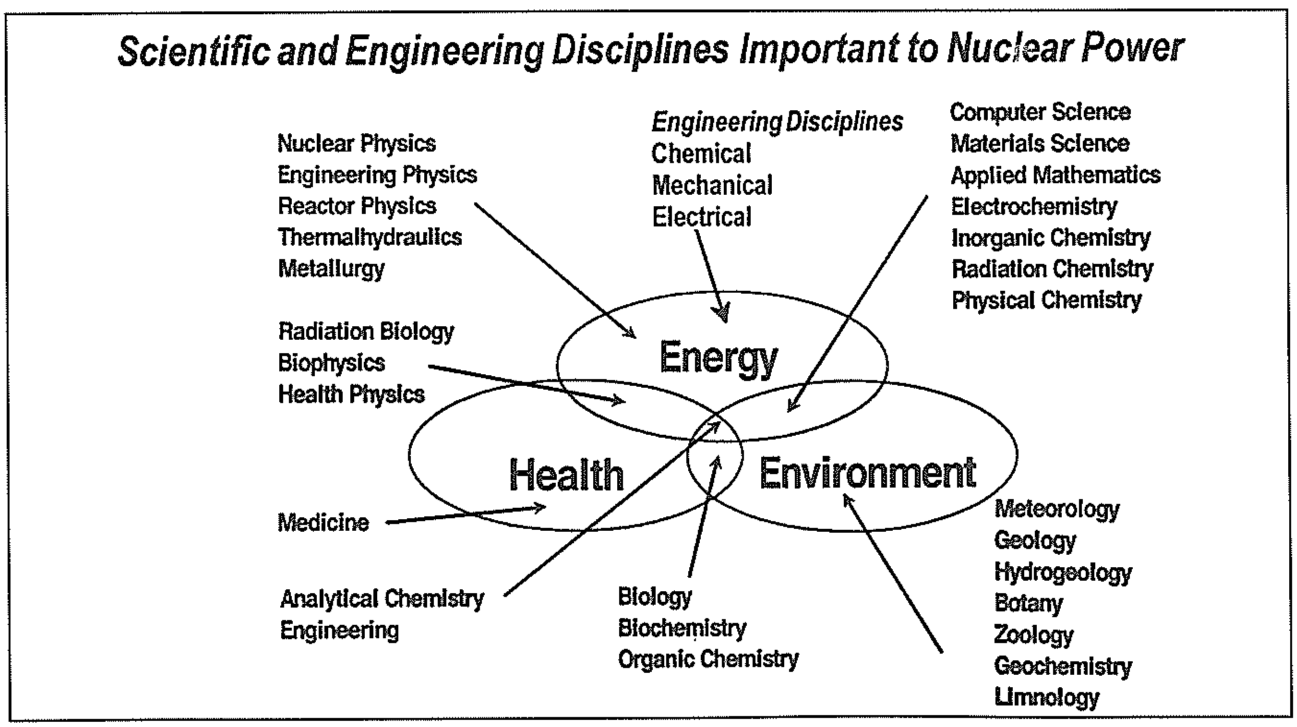

Figure 6: Scientific and Engineering Disciplines Important in Nuclear Power

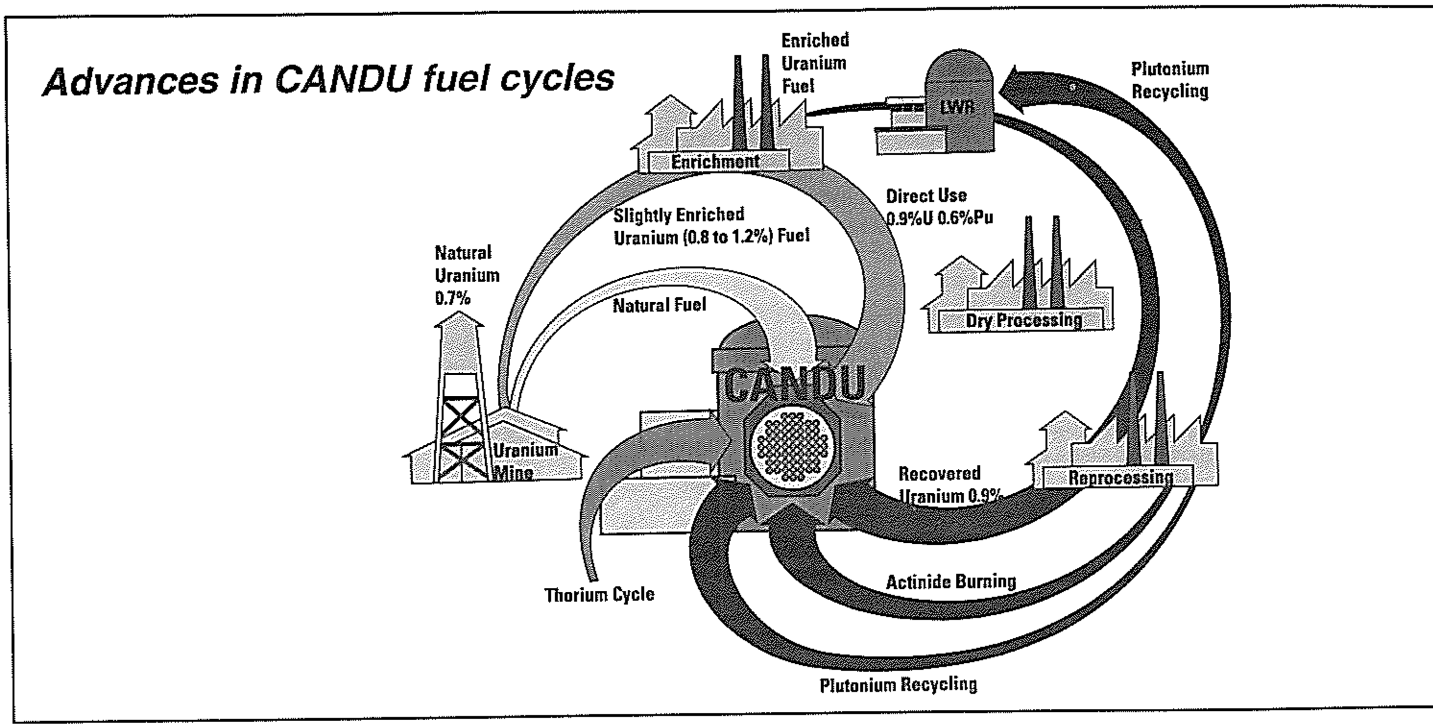

Figure 7: Advances in CANDU Fuel Cycles

The global energy challenge is to meet the potentially vast demands of the next century, while maintaining a healthy environment. Even the most intractable conservationist would find it hard to deny the need for more energy or the right of billions of people, not to luxury, but to the basic necessities that electricity can provide.

The developed nations today have a population of about 1.2 billion people, and that number is projected to remain approximately the same at least up to the middle of the next century.[21] In the same period the population of the developing countries, now 4.5 billion, is predicted to reach 8.6 billion. If one assumes, as one must, that this dramatic population growth is going to be accompanied by economic development, one must ask where the energy is going to come from to power the development and nourish the people. Currently, about 90 percent of the world's energy comes from burning fossil fuels, releasing approximately six billion tonnes of carbon to the atmosphere annually.[22] Coal, oil and gas will continue to be the energy sources of first choice for emerging nations because of the relative accessibility of these sources and the speed with which they can be integrated into growing economies. Growing energy demand will also spur the use of hydro-electric power but, because its accessibility is limited, its proportion of the energy mix will not increase. Similarly, the renewable sources such as biomass, wood, solar and wind will increase but their relative proportions will remain small.

Meeting the needs of the developing world is hard to imagine without recourse to nuclear power. Equally hard to contemplate is the heavy environmental burden that future generations will bear if a massive increase in the burning of fossil fuels precludes the alternatives.

Despite the need for nuclear power, it would be naive to think that the opposition to it will suddenly lessen. Those in the nuclear industry must therefore work harder to ensure that the public receives a balanced picture. While we may not be able to match the rhetoric of the opposition, we are at least accountable, and we owe the public the facts that will help them to make up their own minds. In the final analysis, it is only the appropriate degree of balance in the views of the public that will permit nuclear power to make its proper contribution to the energy supply and to the well-being of the world in the years to come.

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Neutrons in the fight against cancer

A REVIEW REPORT BY MICHAEL LEVINE

On March 1, 1995 Dr. Merle Griebenow addressed attendees in the William Peyton Hubbard Auditorium of the corporate head office of Ontario Hydro on the status of Boron Neutron Capture Therapy. The presentation, which was sponsored by the CNS and open to the general public, was well attended. It is one of a series of talks being given across Canada at nuclear research facilities and hospitals. Dr. Griebenow is president and COO of the Neutron Technology Co., Boise, Idaho.

Boron Neutron Capture Therapy (BNCT) is a technique whereby neutronic radiation is used to activate Boron-10, which has been selectively introduced into tumour cells, thus destroying the malignancy while minimizing injury to the surrounding healthy tissue. The talk summarized the basic biology, physics and pharmacology involved and presented the current status of experimental clinical procedures.

BNCT is a two-step treatment. The patient is first administered a drug which has been designed to preferentially accumulate in cancerous cells (and, possibly, tissues which are physically remote from the area to be treated). These drugs have a high concentration of isotopically-enhanced boron. When the B-10 is subjected to a thermal neutron flux it becomes activated and decays, primarily with the release of an alpha particle, to produce hard radiation with a small mean free path. If sufficient ionizing energy is deposited in the nucleus of a cancer cell it will induce the reproductive death (inability to replicate) of the cell. Since thermal neutron radiation is relatively benign, this procedure potentially offers a largely non-invasive method of selectively destroying tumours. Dr. Griebenow reports that the potential for such a therapy was recognized in 1936, only four years after Chadwick discovered the neutron. Attempts to utilize the technique

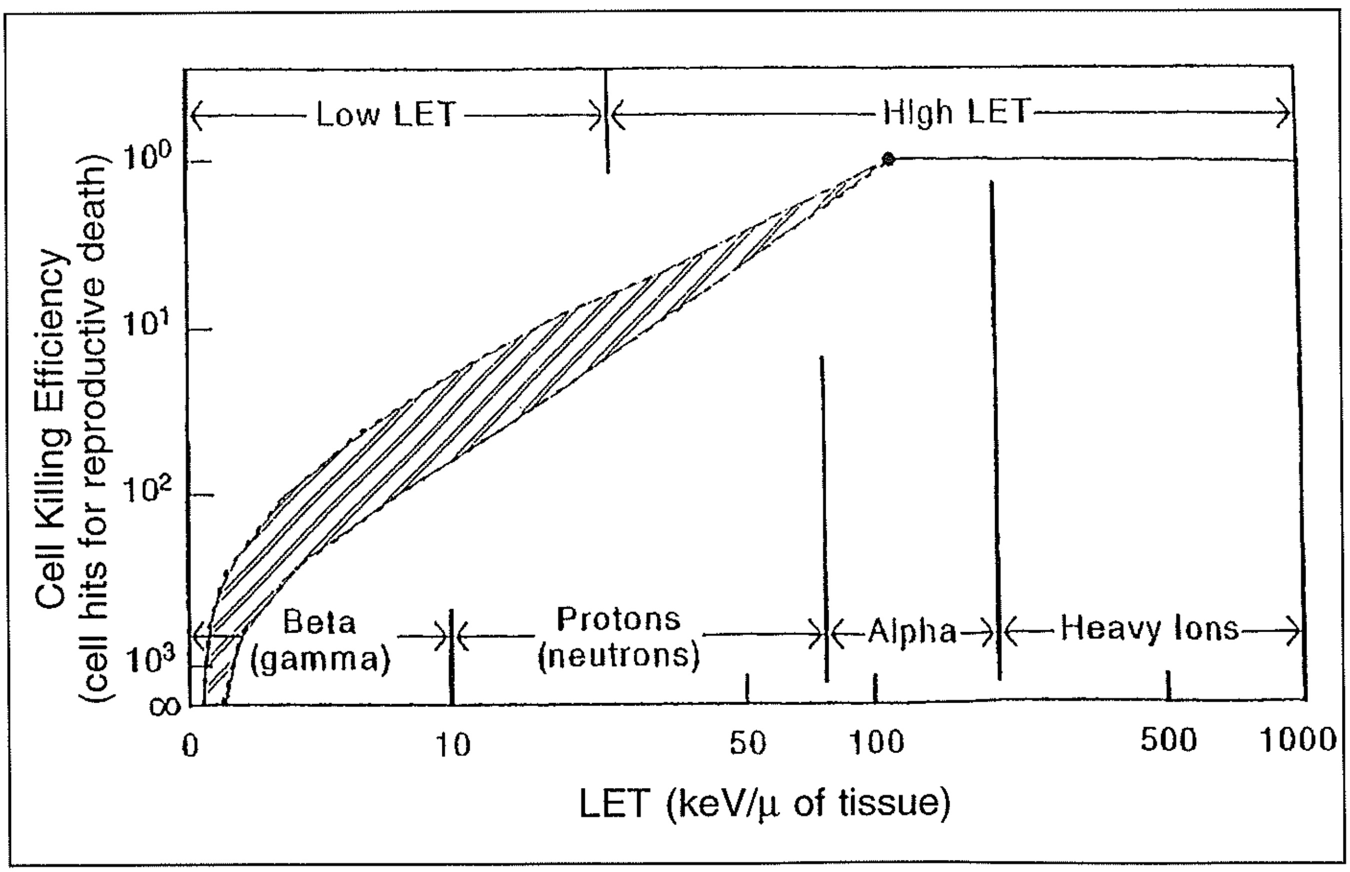

Figure 1: Cell Killing Efficiency vs Ionizing Density

in the 1950's and 1960's failed, largely due to the lack of sophistication then available.

The efficiency of a radiation treatment in destroying a cell is given by the number of hits that are required to kill the cell. This is inversely proportional to the Linear Energy Transfer (LET) deposited in the cell. The LET is greatest for heavy, hadronic radiation such as heavy ions and alpha particles (Figure 1). Typically 25-30 B-n capture events are required for cell death. The great strengths of BNCT are the dose localization and the high LET induced by the secondary radiation. There are three principal difficulties with the procedure. The first concerns the accumulation of sufficient B-10 concentrations in the affected tissues (there is a toxicity limit also). The other two concern the scattering and capture cross sections of the neutrons in tissue and Boron.

The activation of B-10 as a function of neutron energy may be seen in Figure 2. The cross section is largest in the thermal (0.025 eV) range. Unfortunately, a thermal neutron beam attenuates rapidly (Figure 3) as a function of tissue depth. This not only reduces the flux available for deeper sections of the tumour (which are the least operable in the case of brain tumours) but results in damage to skin tissue. Ideally, epithermal neutrons, which cause less damage to the skin, could be thermalized within the tumour. The optimum incident neutron energy is in the 1 eV to 10 keV range. In this range the thermalization depth increases by one centimetre for roughly a 200-fold increase in incident neutron energy and neutron capture is dominated by hydrogen. Above 10 keV the recoil of protons induces strong ionization which is biologically damaging.

Dr. Griebenow discussed at some length the neutron beam requirements as to purity (spectral energy profile) and intensity. Filtering agents are required, whether the beam source is a research reactor or an accelerator. The details depend both on the specifics of the drug used and the initial beam spectrum. There are competing medical and biophysical limitations. These are again dependent upon the type of tumour being treated.

The talk then concentrated on a specific type of tumour and drug. Glioblastoma Multiforme is one of the most vicious and lethal varieties of brain tumour with a nearly 100% fatality rate. The drug which, according to Dr. Griebenow, currently shows the most promise is borocaptate sodium ($NA_2B_{12}SH$), or BSH for short. This variety of cancer causes 5000 fatalities annually in the U.S. and other forms of treatment are largely ineffective. The same treatment should be applicable to most other malignant brain tumours (70,000 U.S. deaths per year). Glioblastoma Multiforme is characterized by tumours of up to 6 cm in diameter plus tumour tendrils extending deep into the surrounding tissue. These tendrils may be missed by conventional x-ray beam treatments which also have an unfortunate tendency to significantly lower the patient's IQ.

Experiments with large laboratory mammals have be performed but these were not elaborated on during the seminar. Instead Dr. Griebenow concentrated on clinical results in humans, principally performed by Japanese neurosurgeons who have been treating terminal patients on an experimental basis since 1968. The technique employed uses thermal neutrons in conjunction with a craniotomy and is limited to tissue depths of approximately 6 cm. A section of the skull cap 10 cm in diameter is removed and the bulk of the tumour surgically extricated (the central portions are dead tissue in any case due to lack of blood circulation). The resultant gap is filled with a neutron moderator and exposed to a neutron beam. A rather tentative statistical analysis of subsequent patient survival was presented but, considering that fewer than 100 patients were treated in this period, one can only conclude that the results appear promising. The most significant factor in determining the survival of a patient appeared to be the depth of the tumour. In one study performed with 38 patients from 1968 to 1985, the survival rate at 64 months following the treatment was 19% overall but 58% among the twelve cases with tumours within 6 cm of the surface.

Dr. Griebenow concluded the talk by speculating on the use of ideal, tailor-made neutron sources. The goal is

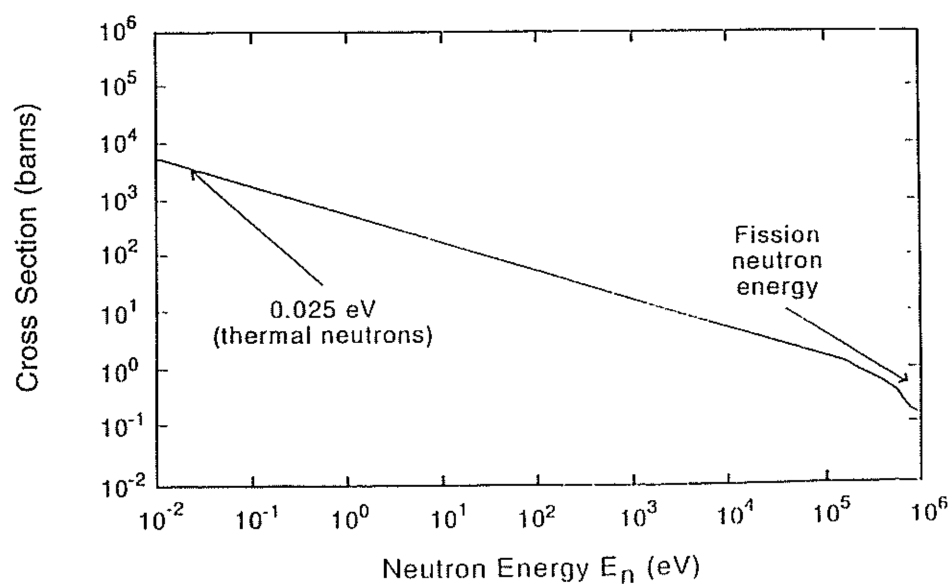

Figure 2. ^{10}B Reaction Rate (Cross Section)

still to treat the patient without surgery via thermalization techniques. The U.S. Food and Drug Administration is currently following a three phase review with the aim of determining whether BNCT is to become an established cancer treatment. He stated that, with more than a half of a million deaths from all forms of cancers every year in the U.S., revolutionary, rather than evolutionary, advances are required.

Merle Griebenow graduated with a degree in Chemical Engineering from Oregon State University in 1957 and spent the next 25 years in nuclear reactor analysis, research and design at the U. S. Atomic Energy Commission's National Reactor Testing Station (now the U. S. Department of Energy's Idaho National Engineering Laboratory – INEL). The final 10 years have been spent organizing and directing INEL's BNCT research and development program. Dr. Griebenow is currently president and Chief Operating Officer of the Neutron Technology Co., Boise, Idaho.

Michael Levine graduated with a BASc in Engineering Science at the University of Toronto and a PhD in physics from Stanford University. He was a post-doctoral fellow at Cavendish Laboratories, Cambridge University before joining the reactor physics group in the Nuclear Safety Department (now Reactor Safety and Operational Analysis Department) at Ontario Hydro in 1990.

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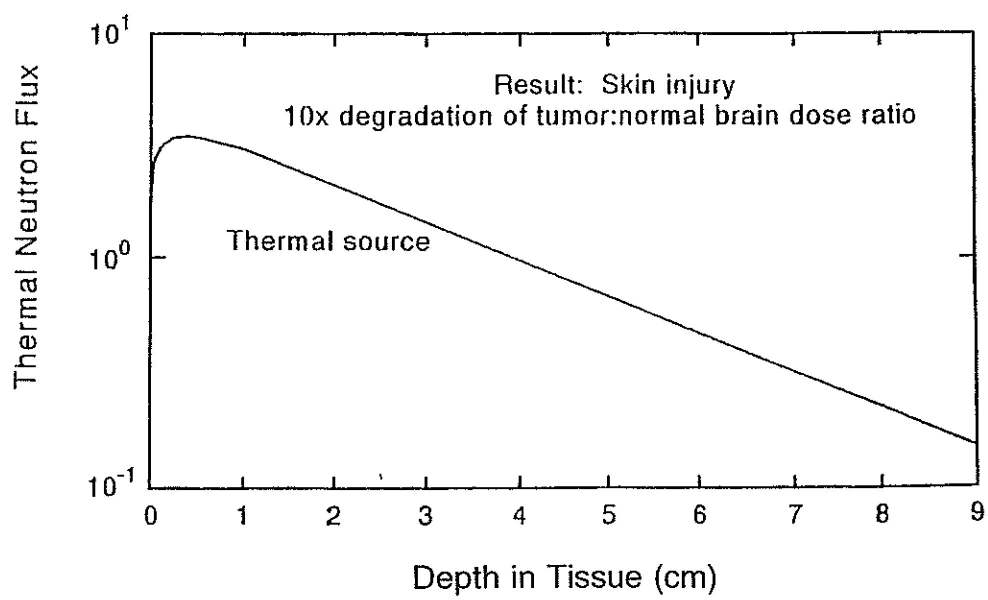
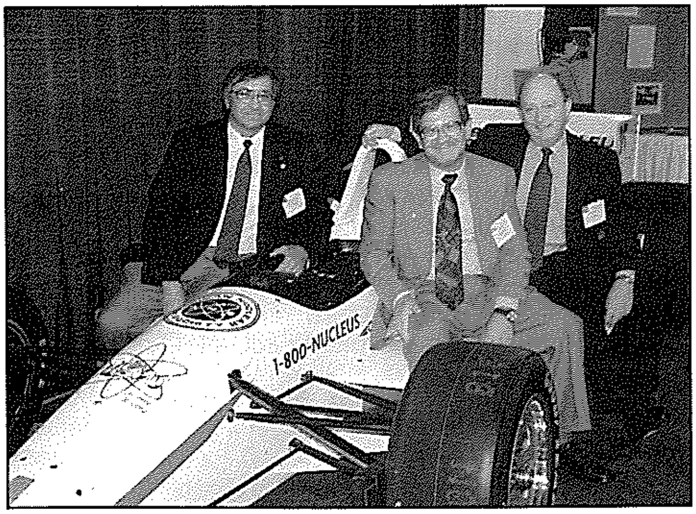
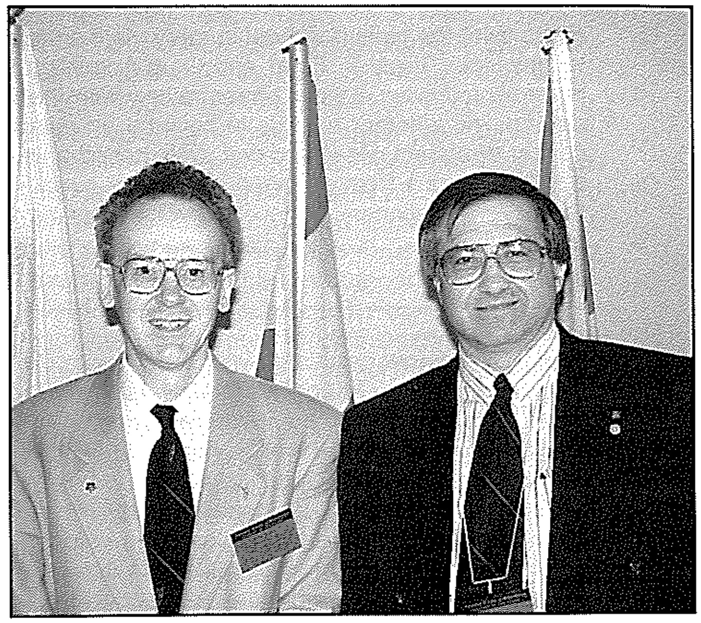


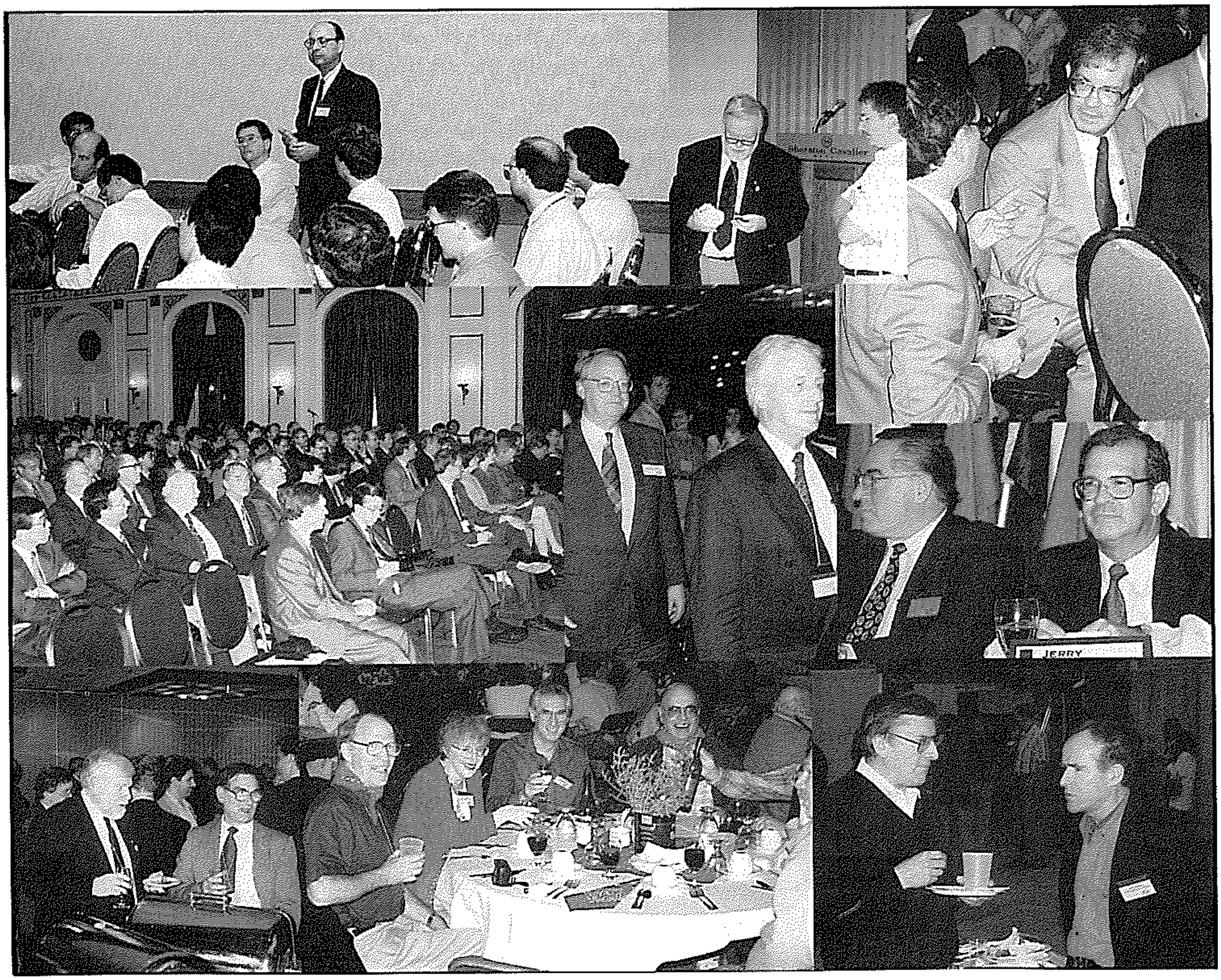
Figure 3. Incident Thermal Neutrons Severely Attenuated at Deepest Portion of Most Human Brain Tumours (~6 cm)



The American Nuclear Society has decided to sponsor an "Indy" type race car as a means of gaining publicity. With, perhaps, dreams of their own car CNS president Jerry Cuttler (centre), vice-president Ben Rouben (left) and former president Ken Talbot (right) pose with the car at the ANS summer meeting in Philadelphia in June.



1995 CNS Conference Co-Chairmen Alan Wight and Ben Rouben



Scenes from CNA/CNS Annual Conference, June 1995, in Saskatoon.

Annual Conference of CNA / CNS
Saskatoon, June 1995

The yearly gathering of the clan, the joint Annual Conference of the Canadian Nuclear Association and the Canadian Nuclear Society took place this year in Saskatoon, Saskatchewan. Despite the impression of some people from central Canada that this "uranium mining capital" is somewhat out of the way there was a good attendance of almost 400 who appeared to be universal in their praise for the excellent organization and running of the conference.

As usual the conference opened with a reception on the Sunday evening, June 4. Monday morning saw two plenary sessions with invited speakers first reviewing the Canadian scene and then international non-proliferation issues.

That afternoon through to Wednesday noon there were, in essence, two conferences running in parallel, the CNA and the CNS. While the former dealt with broader topics such as regulatory issues, trade development and public acceptance, the CNS program, which continued through Wednesday afternoon, presented almost 80 technical papers in four parallel sessions. (See the report by CNS co-chairman Alan Wight and selected abstracts elsewhere in this issue.)

Luncheons each day were part of the program. On the Monday, Dr. Charles Till spoke on the U.S. perspective of the likely directions of nuclear technology over the next half century. He argued that the eventual shortage of uranium would force recycling which could be best accomplished with liquid metal cooled breeders. Tuesday was the time for CNA awards and Wednesday CNS awards. (The latter are described in detail elsewhere in this issue.)

Dr. Robert Morrison, director-general of the Uranium and Nuclear Energy office at Natural Resources Canada was presented the CNA Ian McRae Award, given for exceptional contribution to the Canadian nuclear program other than scientific. Two CNA Outstanding Contribution Awards were made this year, one to Dr. Malcolm Harvey for his leadership in scientific and educational programs at the Chalk River Laboratories and the other to Dr. Norman Sargent for his work in chemistry at the Whiteshell Laboratories.

The social event of the conference was the "Wild Wild West Rodeo" and barbecue held on the Tuesday evening at a ranch outside Saskatoon. Delegates were enthralled with the action at an excellent rodeo show and entertained during dinner by the antics of comedian / singer Kenny Shar.

Following on page 16 are some of the plenary presentations.

Murray Stewart, CNA chairman, presents a CNA Outstanding Contribution Award to Dr. Malcolm Harvey of AECL's Chalk River Laboratories for his work directing science and education programs.

Dr. Robert Morrison (right), Director-General of the Uranium and Nuclear Energy office of Natural Resources Canada, holds the Ian McRae Award presented to him by Murray Stewart, chairman of the CNA at the CNA/CNS Annual Conference in Saskatoon, 8 June 1995.

Four Presentations from Nuclear Industry Leaders

Ed. Note: *The following four articles are drawn from the presentations made by four leaders of our industry at the CNA/CNS Annual Conference held in Saskatoon, June 4-7, 1995. The presenters were: Hikmet Akin, president of Uranerz Exploration and Mining; Don Anderson, general manager, Ontario Hydro Nuclear; Dr. Agnes Bishop, president, Atomic Energy Control Board; and Reid Morden, president, Atomic Energy of Canada Limited. Their thoughts set the tone of the conference and provide insights into the thinking of these influential people.*

Current Status of the Uranium Industry

Hikmet Akin, President, Uranerz Exploration and Mining Limited

The world uranium market is presently undergoing a slow recovery process. Although the present rate of uranium consumption for peaceful purposes greatly exceeds mining production, the spot prices for uranium still dwell at very low levels. Production shortfalls are dominantly being supplied from excess inventories in the west, which are expected to be depleted by the end of this decade. Even if the future market will be supplied by de-enriched weapons grade material, in addition to conventional sources such as mine production and reprocessing, a gap which seems to be developing between uranium consumption and supply, which may allow for the installation of new mining capacities towards the end of this decade.

Canadian uranium production centres, particularly the high grade uranium mines of Saskatchewan's Athabasca Basin, are well-positioned to take advantage of this potential opportunity. The three operating mines and mills, Key Lake, Rabbit Lake and Cluff Lake produced 30% of the world's uranium in 1994. In addition to the recently approved new projects and extensions at Cluff Lake, McClean Lake and Rabbit Lake, environmental reviews will be conducted for the McArthur River, Midwest and Cigar Lake projects in 1995 and 1996.

Difficult past market conditions, some of which are somewhat still continuing, have resulted in a process of emerging consolidation. In the uranium mining industry there is a reduction in the number of production centres as well as corporate entities. On a global basis, the bulk of the competitive uranium production originates from basically two major regions: Northern Saskatchewan in Canada, and Central Asia. Uranium is produced mainly by *in situ* leach technology in Central Asia in contrast to Saskatchewan production which is entirely from open pit and underground mining operations.

Revitalization of the Nuclear Business at Ontario Hydro

Don Anderson, General Manager, Ontario Hydro Nuclear

In the early 1990s, the future of the nuclear program at Ontario Hydro was being seriously questioned. The initial elation with the release of Hydro's Demand / Supply plan, which called for the construction of up to 10 new units, had quickly faded as the recession took hold in Ontario.

Instead of building new units to meet a rising demand for power, Hydro faced a large and prolonged surplus in generating capacity as electricity demand plunged at the same time as the new four unit Darlington nuclear station was coming on stream.

Consequently, the $14 billion cost of Darlington was being added to the rate base just as sales plummeted, forcing double-digit rate increases for three years in a row. This resulted in widespread public criticism of the organization, much of it focused on the nuclear program, which was perceived as expensive and poorly managed.

A number of other factors also contributed in raising questions about the wisdom of Hydro's continued commitment to the nuclear program. These included:

- the poor performance of the nuclear stations compared to the world-leading record of the early 1980s;
- the fuel failure at Darlington Unit 2, which raised questions about Hydro's engineering capability and had the potential to cripple Ontario Hydro financially;
- the derating of the eight Bruce Units to 60 per cent power, following an Ontario Hydro nuclear safety analysis, which identified the potential for a power pulse problem at the Bruce units in the event of a major header break;
- the corrosion of boiler tubes, particularly at the older "A" stations. This raised the spectre of early replacement of the steam generators, which could have meant hundreds of millions of dollars in costs and extended outages.

The restructuring of Ontario Hydro in August, 1993 brought all of the nuclear family together into one organization – Ontario Hydro Nuclear (OHN). OHN was given the mandate to resolve these issues and to revitalize the nuclear program.

Building a Sustainable Business

In the restructuring of Ontario Hydro, OHN was given the resources and responsibility to determine its own future. The business unit operates in large part as an independent business, responsible for meeting income targets, and generating its own cash for capital improvements.

OHN set its sights on a three-year turnaround, which included finding solutions to its technical problems and improving the overall performance of its units. Key to the success of this turnaround are the following:

- with the completion of Darlington, all resources were focused on improving the operation of existing units, rather than building new ones;
- engineering was relocated to the station sites to ensure more effective work relationships with operations staff;
- each division (four generating divisions and seven support divisions) was given accountability and responsibility for its own performance;
- business drivers were introduced into the business to guide decision-making. These include fee-for-service relationships between divisions and the negotiation of contracts for energy production.

Turning the Business Around

OHN has already made significant progress in revitalizing the nuclear business. The Darlington fuel failure problem has been resolved and the four units are recording excellent performance numbers – and providing about 20 per cent of Ontario's electricity requirements. Various fixes to the power pulse concerns are being implemented at the Bruce units, which have been steadily returning to higher power performance. The older boilers are being cleaned, and except for Bruce Unit 2 – whose boilers have suffered extra corrosion due to a lead blanket mistakenly left inside by a maintenance crew – all the steam generators appear capable of serving out their expected service lives.

1994 represented OHN's first full year of operation. By virtually all measures, the year was very successful:

- the nuclear units produced a record 91.1 terrawatt hours, over 60 per cent of Ontario's total electricity production;
- the gross capability factor rose to 76 per cent despite the continued derating of the Bruce units. The four Darlington units exceeded 87 per cent capability factor;
- revenue and income targets were exceeded and other measures, such as chemistry control and low level waste production, show significant improvements;
- four OHN units ranked in the top 15 in the world in terms of lifetime performance – Pickering Unit 7 set a new world record for continuous production.

Continuing Challenges

Unfortunately, what would have been an outstanding year (1994) was marred by the loss-of-coolant accident at Pickering Unit 2 in December. This resulted in a five month shutdown of all four Pickering "A" units. An in-depth investigation identified the cause of the accident, and solutions were developed, approved by the Atomic Energy Control Board, and implemented. Three of the four reactors have since returned to service, and Unit 2, which is subject to a separate AECB approval, is expected to return later this year.

While the Pickering accident will have a major financial impact on OHN in 1995, it won't dampen Hydro's commitment to the revitalization of its nuclear program. OHN continues to benefit from strong Corporate support.

However, the accident was a reminder that the units will present new challenges as they continue to age. OHN is very confident in its capabilities and maturity as an organization in overcoming potential surprises down the road, and in ensuring the plants perform safely and reliably through the rest of their service lives.

More immediate challenges facing the organization are the continued survival of the Bruce Heavy Water Plant (BHWP), which is now reduced to half production, and the retubing of the Bruce "A" units. OHN is confident that CANDU sales abroad and new markets for heavy water will enable the BHWP to survive. OHN is also confident that it will develop the capability of retubing the Bruce A units faster and at a lower cost. The potential use of surplus weapons-grade plutonium as fuel in the Bruce "A" reactors – a proposal that is now being considered by the U.S. government – could also play a major role in helping fund the retubing.

Longer Term Future

The success of the turnaround is now allowing OHN to look further into the future. One of the most important long-term issues is the disposal of nuclear fuel waste. Ontario Hydro takes cradle-to-grave responsibility for its radioactive waste, and intends to take the lead in the nuclear fuel waste management program once the federal environmental assessment hearing makes a recommendation on the disposal concept proposed by AECL.

As far as new nuclear generation is concerned, it is highly unlikely that we will contemplate building a new nuclear plant in the foreseeable future. Ontario is already at the upper limit in terms of the amount of nuclear desirable in a well managed grid system. However, consideration is now being given to what it would take to rebuild and thus extend the lives of the Pickering "A" units once they begin reaching the end of their planned service lives in the new century.

Nuclear Regulation in Canada: The Diagnosis and Prognosis

Agnes J. Bishop, MD, President, Atomic Energy Control Board

The theme of this conference is **Taking Care of Business**, and since, by law, there can be no nuclear business in Canada without the approval of the Atomic Energy Control Board, the AECB's health and outlook are undoubtedly of vital importance to the industry.

Nuclear energy was introduced to the world as a weapon of mass destruction, and it was this safety and security-related application that led in 1946 to the passage of the

Atomic Energy Control Act, establishing the AECB. Over the following dozen years or so, as the fledgling Canadian nuclear industry developed useful, peaceful applications for the new technology, the AECB moved from an immediate post-war focus on the safekeeping of information and nuclear materials to an additional concentration on regulation in the interests of the health of workers and the public. The AECB's controls on the industry evolved with the industry in both scope and depth.

Since 1960, when with the provinces' encouragement and support the first health and safety regulations were established under the *AEC Act*, public and worker health and safety has become the predominant *raison d'être* for the AECB. The overwhelming public interest in the environment that developed in the 1970s and 1980s also helped shape the AECB's current statement of mission: "*To ensure that the use of nuclear energy in Canada does not pose undue risk to health, safety, security and the environment.*"

In the early part of that period, the business of licensing nuclear facilities was quite different from what it is today. For example, specialized advisory committees played an important role in assessing licence applications, a practice that gave way to AECB staff assessment when greater personnel resources were acquired by the Board. The licensing process, though it has never been adversarial, was much less formal 10 to 15 years ago, and it did not depend so much on outside input and influences.

Until 1981, regulations were made and modified by the Board in a relatively internalized and rapid process. Now, new regulations as well as less formal regulatory policies and guides are subject to an extensive consultation process that involves the licensees, the public and special interest groups. Draft regulations are also subject to the federal regulations-making process, which includes the preparation of a comprehensive Regulatory Impact Analysis Statement, and stage by stage publishing in the *Canada Gazette* for comment. All of this takes time, sometimes considerable time.

In the past few years we have acquired a good deal of experience in the application of environmental assessment rules to the licensing process. The requirement for environmental screening, including the all-important assessment of public concern, has radically altered the nuclear decision-making process and in some cases introduced a time-delay factor that is in large measure outside the Board's control.

In January this year, the *Canadian Environmental Assessment Act* replaced the guidelines previously in force. Almost completed is an AECB procedures manual to provide guidance on applying the Act and its regulations to the Board's decision-making process. Although it is intended for use by the AECB staff, this document will undoubtedly be of interest and use to many of our licensees.

In general terms, the environment Act will require similar assessment and review activities to what has become standard for licence approvals under the former guidelines. A significant difference, however, is that the Minister of the Environment may launch a public panel review of a proposed project even if this is not recommended by the Board in its decision pursuant to the Act's requirements. The full ramifications of this are not yet known, but it is evident that in future, licence applicants will need to devote considerable effort not just to the technical elements of proposals, but to the public understanding and acceptance aspects as well.

The new environment Act is a major influence on the way the AECB does business. There are others that arise from time to time, such as the 1992 report of the House of Commons Standing Committee on Finance, whose 46 recommendations included the following with respect to new regulations, all of which have to do with taking care of business:

- the Regulatory Impact Analysis Statement should include an assessment of the proposed regulation's impact on firm *competitiveness* in the sectors where the majority of the compliance costs are expected to occur;
- wherever possible, stakeholders should be brought together at the problem-definition stage of regulation development to reach a consensus on goals, priorities, and allocation of resources for achieving them; and
- all the costs and benefits should be estimated for major proposed regulations.

The cost-benefit issue also arose during the 1993 review of the AECB's regulations and regulatory process by a special panel set up by the Energy Minister, when representations on a variety of regulatory irritants were made to the panel by a number of major licensees.

The application of cost-benefit considerations to the AECB's regulation of the nuclear industry has always proven to be difficult, and has never resulted in much precision. Reasons for this range from society's expectations of better-than-best protection with respect to radiation, through the difficulty of quantifying non-events – for example, what is the overall benefit of an accident *not* happening? There is also the intractable problem of placing a monetary value on a life or life expectancy. Not to be overlooked is the fact that at the levels of radiation exposure found under normal circumstances in the industry, the consequences are largely undetectable, though they can be calculated. If we look at the latest ICRP recommendations as a case in point, it would be fairly straightforward to calculate the cost to an AECB licensee of the public dose limit being reduced from five millisieverts to one, but how do you quantify the benefit?

At a meeting with representatives of the major licensees at the end of March last year to explore the cost-benefit issue it was evident that this is a major preoccupation in some sectors. The AECB also undertook to fund a research project on the subject. The final report of this work should be available for distribution by this summer. The study is expected to identify a framework within which cost-benefit analyses of regulation may be undertaken. Undoubtedly it will call for extensive consultation with industry stakeholders.

The AECB is firmly committed to the improvement of communications with our licensees, and would welcome advice or suggestions on ways to do better in this area. We intend to improve our consultative links with licensees outside the formal regulatory review process, with a view to jointly exploring ways to achieve the same health, safety, security and environmental protection objectives with less or

Dr. Agnes Bishop, president, Atomic Energy Control Board, speaks at the CNA/CNS Annual Conference, 7 June 1995, in Saskatoon.

better regulations.

To guide us into the near future, in the face of the many pressures we now face or can expect, the AECB is developing a business plan. This will outline the changes the agency intends to make over the next five years, in order to continue to fulfil its mission effectively. The plan sets out eight major strategies:

The first is to establish a sound legislative base for nuclear regulation. The intention is to replace the Atomic Energy Control Act of 1946 with a new Nuclear Safety and Control Act. The new Act will correct significant weaknesses in the current legislation and ensure that the nuclear regulatory body has powers commensurate with its responsibilities, both national and international.

The second strategy aims at improved cooperation with the provinces. Discussions and negotiations will be made with the appropriate provincial and federal departments to arrive at the most effective and efficient means of administering nuclear control.

A third strategy is to decrease the duplication and overlap with other federal agencies and departments, through the making of new arrangements for the provision of expertise.

Fourth, it is intended to reduce costs to the federal government. This will be achieved by accelerating the AECB cost recovery program, and by studying new financial arrangements for the basis for funding AECB operations.

The AECB's fifth strategy is to improve the business climate. Without compromising the high standards of health, safety and security, and protection of the environment, the AECB intends to minimize the direct and indirect costs of nuclear regulation borne by the business community in Canada. It will also work towards an international regulatory regime that promotes good regulation of nuclear issues and is receptive to Canadian exports.

The sixth major strategy is to contribute to the international management of nuclear activities. This will involve a number of initiatives to assist developing and newly emerging nations, as well as international agencies, to improve the regulatory controls over nuclear materials and facilities through bilateral and multilateral cooperation.

Strategy seven concerns the non-proliferation of nuclear weapons. It involves support for the Canadian non-proliferation policy, and assistance in the international development of strict controls on nuclear materials usable in nuclear weapons or terrorism.

The eighth and final strategy falls under the heading of "open government." The intention is to open the nuclear regulatory process further, and make it easily and cheaply accessible to all persons in Canada. We will improve consultation with stakeholders in the licensing process, increase efforts to publicize significant licensing decisions in the region where they have the most effect, and hold Board meetings in the vicinity of major nuclear facilities more often.

The AECB expects to achieve the goals set out in its business plan without any reduction in health or safety standards. Given that it's unlikely that the Board will be afforded increased resources in the near future, I believe this places an added importance on the need for good cooperation between the regulator and licensees. Cooperation is of course dependent on communications, and we will be maintaining the commitment to consultation with the industry that we made following the Minister's panel review of the regulations and regulatory process in 1993.

Over the past decade, the AECB and its licensees have seen a gradual transformation that has affected not only the mechanics of the licensing and approval process but also the regulator-licensee relationship. In the decade ahead, there will be further influences, some planned, others imposed by time or circumstance, that will shape the regulatory climate. As change comes about, there will be a need for periodic exchanges of views between the AECB and its license holders and their employees, making consultation a key element in *taking care of business*.

Taking Care of Business

Reid Morden, President, Atomic Energy of Canada Limited

Introduction

Over the past few months I have tiptoed around the theme *Taking Care of Business*. Today, I am going to explore a topic that is central to AECL and the rest of the Canadian Nuclear industry remaining viable and successful over the long haul.

Restructuring an organization has two basic dimensions. The first, and the one that everyone thinks of, is the physical organization of the company – who reports to whom, and so on. This is the stuff of organization charts, and it is clearly important to any company.

AECL announced a reorganization in January of this year. Its purpose was to create one company by integrating what had been largely autonomous divisions. This was done to improve our overall effectiveness and to improve our position in the market.

While it is necessary for organizations like ours to get this right, getting it right provides no guarantee of success in the market place. We all know of reorganizations, both in the private and public sectors, that have produced little change that anyone outside the organization can discern. Such activity is inward looking and time consuming and there is a real chance that in the process everyone will forget about the customer. This leaves the field wide open to competitors.

To my mind a more important dimension of restructuring an organization is its "mental" reorganization. People can generally see the physical organizational constraints that prevent them from doing their jobs effectively. They can understand that a person should have a different reporting relationship and that an individual unit should be part of a different section of the company.

However, far fewer people can readily see the pattern of thought constraints that prevent their organization from achieving its full potential. There is the need to reconsider those underlying assumptions determining the way companies do business, the need to shift operating paradigms, and, to question the appropriateness of existing corporate mythologies.

Such thought constraints exist in all organizations and at the highest levels. For example, here are two that have recently caused the banking industry some problems:

- Countries never go broke.
- They are not making any more land so real estate is a safe investment.

Three Ways of Looking at Change

With this as background, I want to explore three ways of thinking about organizational change that are having a tremendous impact on both public and private sector organizations today. Today the question is not change or no change. The first can be called 'downsizing.' It generally involves significant degrees of cost cutting, reduction in staff and premises and perhaps the sale of parts of the organization that don't fit. A lot of this has gone on in the private sector over the last ten years and government is now taking its turn.

Downsizing may be necessary but it is not totally a future oriented activity.

The second way of thinking about organizational change is '*doing what we do now but doing it better.*' This approach has been talked about in terms of '*re-engineering the corporation.*' It can have tremendous benefits on the competitiveness of companies. In this approach the problem is seen as learning how to get down the road faster.

There are many techniques that can be used by managers to do things better. These include continuous improvement, brainstorming sessions and the like.

The problem with this second approach is that it really only works if two conditions obtain. The first is that the direction the company had been going in the past must have been the right one. The second is that external factors, such as customer needs and constraints imposed by the external competitive environment, have not changed or are not changing. The danger with this approach is that going down the wrong road at a faster speed may actually take you further away from where you need to get to.

The result is that you will go broke – but in a very elegant and efficient manner.

If the second way of looking at organizational change can be characterized as '*doing things better*' then the third way can be stated as '*doing better things.*'

Doing better things is important at this time in our industry. In the first place the needs of our customers have changed and are more complex. They now include elements of energy supply; economic development that is sustainable; environmental impacts; safety; health; and, quality of life. If what we offer does not meet this new matrix of needs, current and potential customers will look elsewhere and we will not be able to attain our goal of increased market penetration.

Now, '*doing things better*' is easier to measure than is '*doing better things,*' at least in the short term. But I want to give you a feeling of how powerful this organizational focus can be. Assume you are proceeding toward a goal but when you reach what you thought was your goal you find that the course you should have charted to reach the real goal was slightly different, say 10 degrees out.

Working out the trigonometry you will find that if I, as President of AECL, had been able to chart the correct course I would have shortened the distance and could have taken the company to its goal between 15% and 20% faster. So you can see what an advantage this approach can be in the competitive market we face.

Some Aspects of the Third Approach

I want to discuss with you a number of important aspects of this idea of 'doing better things.' The first point I want to touch on is how we determine what 'better' things are. If you look at companies in the high technology business that are to some degree supported by government, you will see that many of them have been technology driven, not customer driven. This has resulted in continued government subsidies and a marketplace that is not fully satisfied. As government subsidies and contracts are decreasing dramatically so are the half lives of such technology driven companies.

I am not saying that technology is not important. Quite the contrary. This is and always has been our strength. But it is not enough. The real question is, for what purpose is the technology to be developed and used? This leads us straight back to the customer. Now being 'customer focused' is a concept that has a lot of lip service paid to it.

But, really becoming customer focused is hard to achieve and it is especially hard in a company where technology use and development is both a key element of competitive survival and occupies a lot of management's time. The good news is that there are some simple ways to get better at this. One is to create more situations where we meet with our customers face to face and then communicate with them effectively. Why meet with them? Because about 75% of what we take in is done visually. If we do not spend time with them we are artificially restricting our potential competitive advantage.

So what do we do when we meet with them? Well, we should listen to what they have to say. This may sound easy to do but experts tell us that it isn't. Research has shown that, on average, people take advantage of only 25% to 30% of their listening capabilities.

Organizations like AECL spend enormous amounts of time producing words for clients. Yet little of what people take in seems to be through words alone. I can have the best words in the world in this speech but the deck is stacked against me. On average we only remember about 10% of what we hear. But we do remember 50% of what we see, and best of all, we remember 90% of what we do.

Becoming customer focused is part of what is known as marketing. I think that what the nuclear industry has called marketing is perhaps better characterized as 'technical selling.' But selling is getting rid of what you have. What we really need to do is to get what we can get rid of. This is real marketing.

I have used the word 'we' a lot already and I am going to use it a lot more before I am finished. There are two "we's" in my mind – AECL and the Canadian Nuclear Industry, of which AECL is a part. History has shown us that, where a group of companies can work together to their mutual benefit, each company is better off than if it worked alone. What I feel we need now is a new and realistic model of how Canadian industry can work together to the benefit of all.

Call it Team Canada if you will but no company should buy in based on an emotional sell. Alliances built on this basis don't work in the long term. What I want is a hard headed approach to defining the terms under which we can work together, and one in which each part clearly sees the benefits it will receive.

What should our common focus be? I think not just selling reactors. For the many newly developing markets out there the reactor is merely the last step in a long process that begins with the determination of their key needs.

Our marketing effort can and should begin as far back as collaborating with the stakeholders in the client country to assess their future electricity needs and to determine the place nuclear might have within that. Many of the markets we want to enter have not yet taken these types of national decisions and we can help shape them. We need to be part of this decision making process.

A few countries like Korea and China have already made many of these fundamental decisions and have built their infrastructure. However, they are now confronted with with another series of systemic decisions relating to the advantages of having more than one reactor type. We need to play a part in this decision making process.

We can't speak about being customer driven without dealing with the subject of waste disposal. Whatever the solution to this issue, we had better be active in addressing it with the customer.

This is an example of where we can do a better job – working together. Perhaps our goal as an industry should be to become what I would term a 'full cycle vendor.' I think the industry as a whole should examine this idea and meet together to try to work out how this might be done. We don't even need to see all the steps but we do need to be clear about the first one.

In trying to 'do better things' we need not rely only on ideas that are generated internally. Our relationships with our customers have a number of basic characteristics:

- there are relatively few potential customers at any one time;
- there is a long run-up period to the sale during which there are many key decision points;
- there is a relatively long construction period;
- the prospects for repeat business can be important; and
- potential customers have different social and economic priorities than we do and they work in different business and cultural environments.

For example, the Asian markets that AECL is currently concentrating on tend to have a much higher emphasis placed on relationships and trust. This may well be because most Asian countries are less reliant on the legal and financial frameworks that we have come to regard as necessary to provide a predictable business environment. Therefore, relationships become at least a partial substitute.

These characteristics can appear somewhat daunting but other industries have in common with us these same types of relationships with their customers: the telecommunications industry, those involved in major capital projects, and the aircraft industry, to name but three. In reaching for a better relationship with our customers surely there are lessons to be learned from companies involved in these industries. In reviewing our marketing strategy we are trying to learn from such companies.

A second aspect of this idea of 'doing better things' is choosing the goal and staying the course. One answer to goal setting that enjoys a certain following is that of developing a 'corporate vision.' I know that this process has been useful to a number of companies but I do think that the process itself has some flaws. The people in history who have been favoured with a vision have shared three characteristics:

- First, they worked very hard to get it.
- Second, a very small number of visions were sufficient to carry these people through their lives, and
- Third, the visions received were very personal.

Contrast this with the current business environment where a consultant can pack a room full of executives and produce a corporate vision between 10:00 and lunch.

We do need a vision but not that sort. What I think we need is a vision that comes in the form of an ongoing dialogue that points the way, deepens commonly held understandings, and provides our people with the energy needed to accomplish the tasks required to get there. How to create that dialogue and build the energy is something we at AECL are working on right now.

We have in AECL an organization that is learning about technology on an ongoing basis. I want to mirror that approach in the way we deal with our customers. I also want an organization that does this learning faster than our competitors do it. One of the common attributes of people that work at AECL is that they never get tired of learning. By developing a culture of ongoing customer-oriented learning AECL can become more responsive to this pervasive desire to learn and can become an even better place to work than it is.

A few minutes ago, I used the phrase 'staying the course.' Once we know where we need to get to it is not a matter of drawing a straight line between that place and where we are right now and then following it. Just like an aircraft facing any kind of cross wind our organizations are bound to be off course at least 90% of the time. The skill here is to know when and why we are drifting off course and then to make the appropriate course correction quickly.

Conclusion

From a management perspective, the way in which we think about the kind of change our organizations need to go through has tremendous implications for the type of actions we take. It also strongly influences the way in which people working at all levels in our organizations think and it influences what they pay attention to.

I have shared with you some thoughts on the 'mental' restructuring of our organizations and on differing ways of going about achieving meaningful change. The implications of the idea of teaching the organization to 'do better things' are providing much food for thought for me and for others in AECL. My hope is that it will be one vehicle among many that will help us achieve a significantly increased and profitable presence in the world nuclear industry.

To conclude:

The status quo is not a viable option for the future.
Our industry must take bold steps.
Both as individual firms and, more importantly, working together.
We, at AECL, cannot do this alone. And even if we could, we should not.
Canada needs the industry to work together.
That way we can indeed **do better things.**

16^{th} Annual Conference of the Canadian Nuclear Society

by Alan Wight

Saskatoon, City of Bridges, was the setting for this year's highly successful CNS Annual Conference. Over 350 delegates gathered from June 4 to 7 in the Sheraton-Cavalier and Bessborough Hotels for the combined 35th Annual Conference of the Canadian Nuclear Association and the 16th Annual Conference of the Canadian Nuclear Society. The Conference included tours of uranium mines in northern Saskatchewan and an open house at AECL's new design office in Saskatoon, in addition to very full CNA and CNS Programs. A "Wild Wild West Night" rodeo and barbecue gave the Conference a distinctly western flavour.

The CNS Program included 72 technical papers arranged in sixteen sessions. Sessions ran in parallel four at a time Monday afternoon, Tuesday morning and afternoon, and Wednesday afternoon. CNA/CNS plenary sessions opened the Conference Monday morning and ended the CNA portion Wednesday morning. Approximately 20 to 40 people attended each CNS session with delegates moving frequently between sessions. Session chairs did an exemplary job of keeping their sessions running on time and synchronized.

Three sessions containing a total of 14 papers dealt with various aspects of **Thermalhydraulics**. Sessions were chaired successively by W.J. Garland of McMaster University, J. Luxat of Ontario Hydro and H.M. Huynh of Hydro Quebec. The papers covered the investigation of the basic equations, experiments and computer simulations of two-phase flow phenomena, design, modelling techniques, critical heat flux, system response to transients, and vibration analysis.

R. Fluke of Ontario Hydro chaired a four paper session on **Containment**. Topics ranged from hydrogen behaviour in containment to methods of improving containment design.

M. MacBeth of AECL chaired the session on **Control and Instrumentation**. Four papers covered such diverse topics as alarm systems, human factors plans, control room design and fuel handling control systems. A common theme was the increasing awareness in the industry of the human factors component of the design process.

The **Reactor Physics** session was chaired by G. Hotte of Hydro Quebec. A total of seven papers were presented, three on reactor core calculations, one on lattice cell calculations, one on supercell calculations, one on detector probes and one on the International Thermonuclear Experimental Reactor (ITER).

Two sessions on **Fuel Channels** were chaired successively by A.C.D. Wright and E.G. Price of AECL. The nine papers dealt with various aspects of fuel channel technology including design, experiments, analysis, instrumentation, pressure and calandria tube behaviour, simulation and computer code validation. Developments presented in these sessions contribute to understanding key issues in fuel channel technology and promise to have a positive impact on fuel channel performance and safety margins.

Two sessions on **Engineering and Maintenance** covered a wide variety of topics. A total of eleven papers discussed seismic analysis, concrete properties, spent fuel storage, radiation effects on adhesives, procedure diagrams, shield tank design, quality engineering, modular construction, leak repairs, tritium removal, and waste water analysis.

P.D. Thompson of NB Power chaired a session on **Safety and Licensing**. Five papers were presented before a packed house of enthusiastic conference attendees. Topics ranged from novel and innovative inherently safe reactor concepts to events in operating reactors. Two papers dealt with the fuel string relocation problem in Bruce. The session wound up with a paper on a streamlined approach to licensing new reactors.

J.T. Rogers of Carlton University chaired a session entitled "**Severe Accidents and PSA**". Two papers were presented in the session, one on probabilistic safety assessment and the other on seismic risk analysis.

Five papers on **New Reactors and Applications** were presented in a session chaired by D.A. Meneley of AECL. Topics covered included particle accelerators, research and isotope reactors, nuclear steam supply for oil sands development and new CANDU reactors.

The session on **Radiation**, chaired by H.S. Caplan of University of Saskatchewan, dealt with a diverse spectrum of radiation related topics. Three papers discussed the biological effects of radiation, one paper dealt with transport of radioactive materials and one paper dealt with radiation shielding analysis.

Five papers on **Fuel** dealt with simulation of experiments, fuel pin modelling, irradiated sheaths, fretting and fission product release. P. Boczar of AECL chaired the session.

M. Saari of AECL chaired a session of two papers on **Computers**. One dealt with software validation and the other with neural networks.

T.M. Holden of AECL, the 1994 CNS Innovative Achievement Award winner delivered a **Special Presentation** to a joint plenary session of CNA and CNS. Dr. Holden's paper was entitled: *"The Application of Neutron Diffraction in Material Science Problems in the Canadian Nuclear Industry"*.

The CNS luncheon on Wednesday noon featured the CNS awards presentations and a talk by George Spark on the early history of AECL's presence in Saskatchewan.

The CNS Conference Co-chairs, A.L. Wight and B. Rouben of AECL would like to thank all the people who made this year's conference such a success. Forty-one technical experts from a variety of disciplines on the Technical Review Committee ensured the high quality of the papers presented. The sixteen session chairs ran their sessions with clocklike precision and generated much stimulating discussion. And a final thank you to the 72 presenters who took the time and trouble to present their work to the Conference.

Proceedings of the Conference may be purchased from the CNS office.

The Application of Neutron Diffraction to Materials Science Problems in the Canadian Nuclear Industry

T.M. Holden, J.H. Root, R.B. Rogge and A.P. Clarke

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Ed. Note: *In 1994, the Canadian Nuclear Society presented Dr. Tom Holden the CNS Innovative Achievement Award for his accomplishments as leader of the Applied Neutron Diffraction for Industry group at Atomic Energy of Canada Limited's Chalk River Laboratories. The CNS them invited Dr. Holden to present a paper on his group's work to a plenary session of the CNA/CNS Annual Conference held in Saskatoon, Saskatchewan in June 1995. Following is that paper.*

Text of paper presented at CNA Conference, Saskatoon, 7-11th June 1995.

Abstract

Diffraction is one of the principal tools of the scientist for studying materials. The diffraction pattern yields the spacing of the atomic lattice, which characterizes the chemical and physical state of the material. The broadening of the diffraction lines provides information on the degree of cold-work and their intensity gives the degree of crystallographic alignment or texture generated in the manufacturing process. The main advantage of neutron diffraction over X-ray diffraction is that thermal neutrons easily pass through, for example, 25 mm of steel, so that measurements can be made at depth in engineering components. A program at Chalk River to investigate the industrial applications of neutron diffraction began with measurements on over-rolled Zr-2.5Nb pressure tubes, a topic of major concern in the eighties. It was quickly realized that neutrons could provide measurements of residual stress accurate enough to be of real interest. Over the ensuing period, major contributions have been made in measuring stresses and crystallographic texture in components for the nuclear industry including end-fittings, steam generator tubing, pressure tubes and calandria tubes, and weldments. In addition to work for the nuclear industry, there have been many applications in the aerospace, automotive, defence and pipeline industries in Canada and throughout the world.

Residual stresses arise because of inhomogeneous plastic deformation of the material. Inhomogeneous plastic deformation not only occurs on a macroscopic scale but also on the scale of the grain size. The stresses that occur on this scale are called intergranular or type-II stresses. These intergranular effects, taken with the strong crystallographic alignment in zirconium alloy tubing, determine the growth of components in the reactor environment. Systematic studies of the origin of intergranular residual stresses arising from thermal effects and plasticity effects were carried out on Zircaloy-2 and Zr-2.5Nb alloys which have led to a theoretical understanding of component growth. Finally, a very recent texture scanning technique was able to shed light on the microstructure of zirconium alloy components.

1 Introduction

The property of thermal neutrons that makes them valuable for testing industrial components is their high penetration through widely-used industrial materials such as aluminum, steel or zirconium. This means that neutron diffraction can be used as a non-destructive probe to obtain residual stress and crystallographic texture information deep within engineering components. Diffraction is one of the main tools of the scientist for studying metals and ceramics. The positions of diffraction peaks yield the spacings of the atomic lattice which characterize the chemical and physical state of the material. The broadening of the diffraction lines is related to the plastic deformation which the material has undergone and the intensities of the diffraction peaks are related to the degree of crystallographic alignment, or texture, of the grains making up the material. With neutron diffraction we are able to measure lattice spacing as a function of position in the component, and it is a short step from this to infer the magnitude of the lattice strain and then to calculate the stresses.

The NRU reactor was built at Chalk River in 1957, and at that time it was the world leader in neutron flux at 3×10^{14} neutrons cm^{-2} sec. It still has about the fifth highest flux in world after 38 years of service. In addition to engineering testing and isotope production the reactor has been used for neutron beam research over this whole period beginning with the seminal experiments of Nobel Laureate B.N. Brockhouse in inelastic neutron scattering. By the 1980's the funding of basic research throughout the world was less assured and under funding restraints scientists began to look for applications of their expertise. The first tests were made at Harwell by the group of Windsor and Hutchings, who produced an early review of the field[1]. Shortly thereafter, S.R. McEwen carried out some interesting experiments[2] at the Argonne National Laboratory on intergranular stresses in Zircaloy-2. This acted as a stimulus for us to begin work at Chalk River on over-rolled pressure tubes[3], a topic of major concern at AECL in the eighties. It was soon realized that neutrons were capable of providing accurate measurements of residual stress for the Canadian nuclear industry and, as we began to refine the technique, an increasing variety of applications became apparent.

There were several key components in pursuing this program effectively. The necessary expertise and equipment existed at Chalk River to optimize the measurements, since changes in the fourth decimal digit of the lattice spacing have to be measured accurately. The equipment, a highly sophisticated triple-axis crystal spectrometer developed by Brockhouse, was able to do the job with minor modifications. It was very important to work with knowledgeable engineers and metallurgists who were able to advise the technique practitioners of the important problem areas. Over the years we have developed the methods necessary to do high precision lattice-spacing measurements on bulky and heavy components such as lengths of rail steel, large section girth-welds or shielding flasks containing radioactive material. We continue to develop ways of speeding up the measurements without sacrificing accuracy, so that neutron stress measurements remain an attractive and economic proposition to our customers.

Residual stresses occur when there has been an inhomogeneous plastic deformation of the sample, in which some parts have been plastically deformed in manufacture whereas other locations have only been elastically deformed. This can happen on a macroscopic scale as in a permanently bent bar, where regions near the surfaces have been deformed plastically, but regions near the neutral axis have deformed elastically. This situation is analogous to the case of a bent steam-generator tube which we will later consider. Inhomogeneous plastic deformation also occurs on the scale of the grains, where some grains with particular crystallographic orientations, say the cube edge [002] direction in a cubic material, deform elastically whereas grains with other orientations, for example the body-diagonal [111], deform plastically. The two types of stress are labelled macrostress and microstress and both can affect performance as we will discuss. Residual stresses are important because they add to applied stresses, so that the yield point may be exceeded unexpectedly in local areas. Tensile residual stress fields favour crack propagation thus reducing fracture toughness. Conversely, compressive fields, such as those generated by shot-peening, mitigate against cracks. A very complete book on residual stress has been written by Noyan and Cohen[4] and a review for a general audience on neutron stress measurements has been written by Krawitz and Holden[5].

The examples chosen in this paper to illustrate the technique were all drawn from our experience in carrying out measurements for the Canadian nuclear industry and include work on rolled joints, welds, pressure-tubes and calandria tubes and steam generator tubing.

2 The Neutron Technique

The basic equation underlying all diffraction measurements of strain is Bragg's law

$$\lambda = 2d_{hkl}\sin\theta_{hkl} \qquad (1)$$

where d_{hkl} is the lattice spacing between interatomic planes characterized by Miller indices *(hkl)*, $2\theta_{hkl}$ is the angle through which the neutrons are diffracted and λ is the wavelength of the monochromatic incident beam, calibrated with a standard powder sample such as silicon. To determine the elastic strain, ε_{hkl}, from the lattice spacing requires a knowledge of a stress-free lattice spacing, d°_{hkl}, as follows

$$\varepsilon_{hkl} = (d_{hkl} - d^{\circ}_{hkl})/d^{\circ}_{hkl}. \qquad (2)$$

To determine d°_{hkl} a reference sample must be prepared, or scientific intuition must guide us to a location which is likely to be stress free, since neutron measurements are made inside the material where the stress-state is generally triaxial. Stress-balance considerations can also lead to a good reference value.

In general, interest focusses on the variation of stress as a function of position in the sample, for example the distance from a weld in a plate. The incident and scattered neutron beams are defined by slits in neutron absorbing cadmium masks placed before and after the sample as shown in Fig. 1. The strain information only comes from the region of intersection between the incident and scattered beams, which is referred to as the gauge volume. Typically, the gauge volume is 5 mm^3 but some experiments have been carried out with volumes as small as 0.5 mm^3. By moving the sample on an XYZ translator, any point in the sample may be moved into the gauge volume and the strain measured. The strain is measured only along the bisector of the incident and scattered beams since diffraction only occurs from the grains with plane normals in this direction.

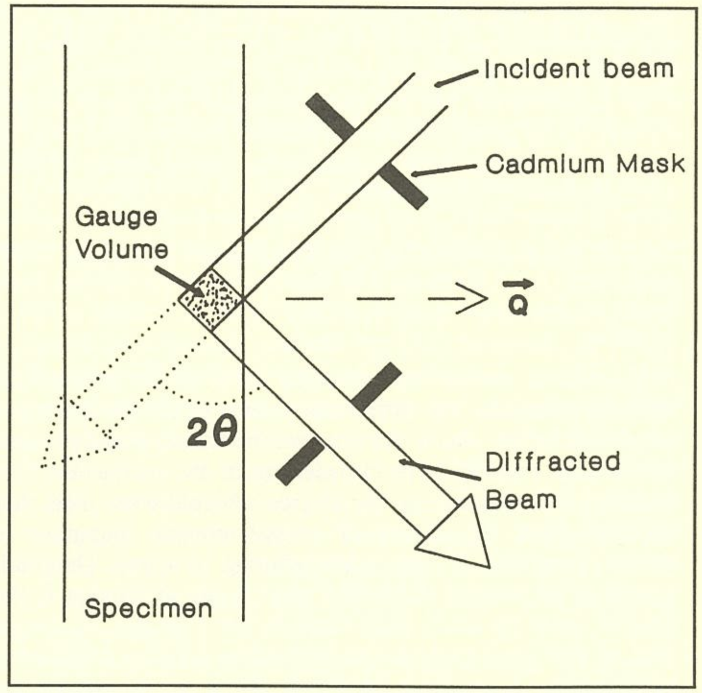

Fig. 1 Experimental arrangement for measuring the spatial dependence of residual strain in a sample. Slits in absorbing cadmium placed in the incident and scattered beams define the gauge volume, the region from which the diffraction peak information is obtained.

Hooke's law provides the relationship between the measured principal elastic strains, ε^{i}_{hkl}, and the stresses, σ^{i}, for example,

$$\varepsilon^{1}_{hkl} = \frac{\sigma^1}{E_{hkl}} - \frac{\nu_{hkl}}{E_{hkl}}\sigma^2 - \frac{\nu_{hkl}}{E_{hkl}}\sigma^3 \qquad (3)$$

where E_{hkl} and ν_{hkl} are diffraction elastic constants for the particular [*hkl*] direction. These constants may be determined experimentally by subjecting the material to a known stress and measuring the resulting strains for various planes. Alternatively they may be calculated from single crystal properties.[6,7]

A material is said to be crystallographically textured if it has a non-random distribution of crystallite orientations. Industrial processes involving plastic deformation always generate texture. The distribution of orientations is obtained by measuring the intensity of the diffraction peaks as a function of tilt and azimuth. Texture is important in its own right, in determining the plastic flow of components. As an example, texture determines whether beverage cans are mis-shapen in manufacture. It also effects the interpretation and planning of stress measurements.

3 Measurements of Macroscopic Strain Fields

3.1 Over-rolled Pressure Tube[3]

In a CANDU® reactor the pressure tubes are attached to the end-fittings by rolled joints as illustrated in Fig. 2. To make a joint, the tube is slid into the end-fitting, which has three circumferential grooves machined in it. To aid the insertion of the pressure tube into the end-fitting, the inside of the inboard end is tapered by a few degrees. A rolling tool is inserted from the outboard end and forces the pressure tube into the three grooves in the end-fitting to make a seal. In a correctly made joint, the deformation of the pressure tube ends where the taper begins and the thrust of the rolls is carried by the end-fitting. In over-rolled joints, the rolling begins too far into the pressure-tube, with the result that the tube flares into the tapered region, generating high residual stresses. These, combined with operating stresses, may lead to concentration of deuterium in this area, reorientation of zirconium deuterides and consequent cracking.

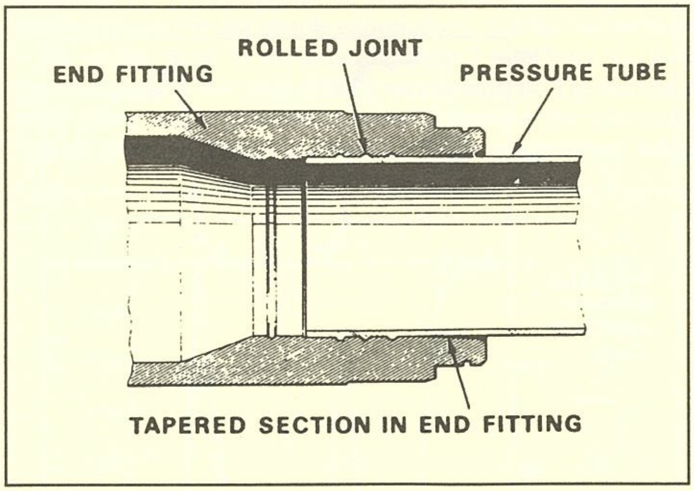

Fig. 2 Rolled joint in a CANDU reactor, showing the pressure tube, end fitting and the location of the grooves.

Zirconium alloys, which possess the hexagonal close packed structure at room temperature, are plastically anisotropic i.e., the individual crystals are easily plastically deformed in directions perpendicular to the hexagonal axis and much less easily deformed parallel to the hexagonal axis. As a result of this property, when tubes are extruded there is very strong grain alignment. The c-axes of individual grains, [0002], are heavily concentrated in the hoop direction of the tube while the prism directions $[10\bar{1}0]$ are very strongly aligned along the tube axis. Fig. 3 shows a schematic diagram of the grain alignment of a pressure tube. Grain 1 refers to the "ideal orientation" of grains. To find out how most grains are behaving, one would examine the (0002) reflection for the hoop component of strain, the $(10\bar{1}0)$ reflection for the axial component of strain and the $(\bar{1}2\bar{1}0)$ reflection for the radial component of strain. Fig. 4 shows the hoop strain for an over-rolled pressure tube (not a radioactive one!) with very large tensile hoop strains about 20 mm down the tube and beneficial compressive strains closer to the end-fitting. The reference lattice spacing in this case was the value well away from the end-fitting, so the measured strains arise from the overrolling and the constraint of the end-fitting. Subsequently the pressure tube was slit and a 12 mm wide coupon extracted. The results on the coupon are also shown in Fig. 4. The effect of the cutting is to remove part, but not all, of the residual strain. This result taught us a very important lesson. If we think of a pressure tube as a homogeneous "continuum" of material we will probably underestimate the effects. Deformation affects the individual crystals making up the material and different crystallographic orientations of crystals deform quite differently as was mentioned above. In this case the plastic deformation produced by overrolling has led to intergranular stresses which are not relieved by slitting because they are on the scale of the grain size. These stresses can still have deleterious effects because the grains are all aligned.

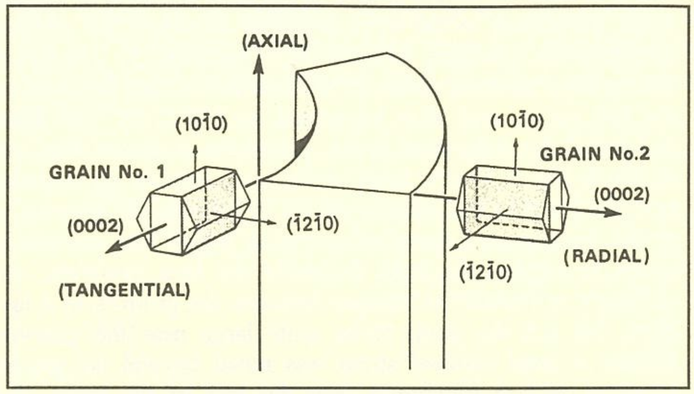

Fig. 3 Schematic representation of hexagonal close-packed grain alignment in Zr-2.5Nb pressure tube material. Grain 1 represents the ideal orientation of grains, while grain 2 corresponds to a rotation of 90° about the $[10\bar{1}0]$ direction.

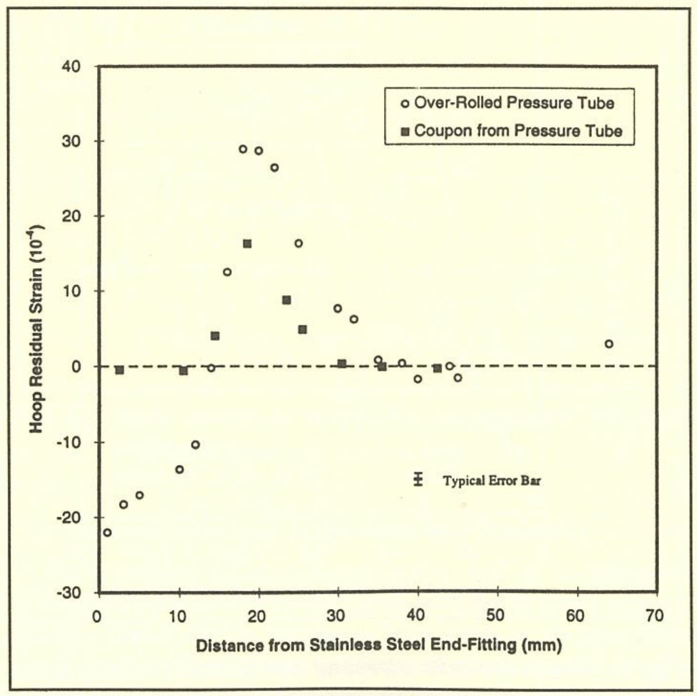

Fig. 4 Hoop residual strains in an intact overrolled Zr-2.5Nb pressure tube and in a coupon cut from the pressure tube. The cutting process has removed the macroscopic strain field but intergranular residual strain effects remain which are large.

In parallel with these early neutron efforts there was a program of stress measurement by slitting and strain-gauging and good agreement was registered between the two methods.

3.2 Prototype Rolled Joints

In the late 1980's, a prototype rolled joint was considered for the CANDU-3 reactor with a less massive end-fitting than previously used. In this case the end-fitting was only 0.25" thick, but was supported during the rolling operation with a strong backing. The question of interest here is the magnitude of stress in the end-fitting near the three grooves. The advantage for neutron experiments is that measurements can be made through the end-fitting and through the pressure tube. (In the previous experiment part of the hub had been machined away to access the over-rolled region.) Since the steel end-fitting was not strongly textured the (110) peak of the body-centred cubic structure of iron was used for measurements in the three principal directions. From the strains in the three principal directions the residual stresses were calculated with the aid of equation (3). The result[8] for the hoop stresses, observed in the as-rolled state indicated by the full curve, and after an anneal at 350°C for 350 hours designated by individual points joined by a dashed line, are shown in Fig. 5. Firstly, large tensile hoop stresses are observed near the grooves and smaller values in between the grooves as would be expected from an operation which was essentially trying to expand the hub. Secondly the heat treatment was sufficient to reduce the stresses between the grooves to a low level, but left the hoop stress quite large near the grooves. Thirdly a large residual stress was noted beyond the groove locations with a maximum near the end of the taper. The material for the endfitting was changed to take account of these results.

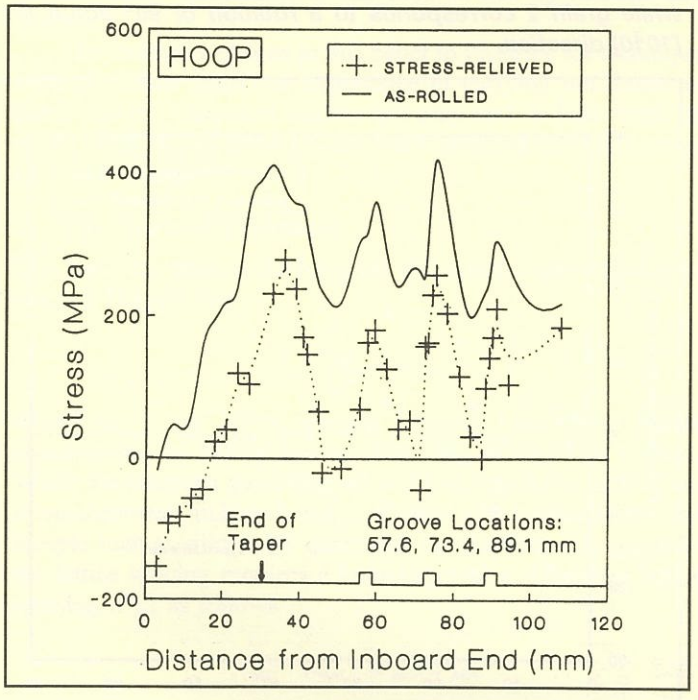

***Fig. 5** Hoop residual stresses calculated from the hoop, axial and radial strain components in the vicinity of an end-fitting. The solid curves represent a spline fit to the hoop stresses prior to a heat treatment at 350°C for 350 hours.*

3.3 Residual Stress and Texture in Welds[9,10,11]

Zr-2.5Nb is widely used in the petrochemical industry, as well as in the nuclear industry, because of its strength and its corrosion resistance. The economically favoured mode of joining tubing is by welding and electron-beam welding gives a particularly good product. Some of these welds were examined by neutron diffraction. The welds were between 4 and 5 mm wide at the base and the surface of the tube was discoloured over a width of 11 mm. The crystallographic texture was similar to that indicated in Fig. 3 with the majority of grains having a [10$\bar{1}$0] direction along the tube axis and an [0002] direction tangential to the tube. In a measurement of the axial strain the (10$\bar{1}$0) reflection is expected to be strong and similarly for the hoop strain, the (0002) reflection is expected to be strong. Fig. 6 gives the variation of intensity of these peaks through the weld, where C_L denotes the centreline, L the edge of the weld and D the extent of the oxidized region. Approaching the weld,

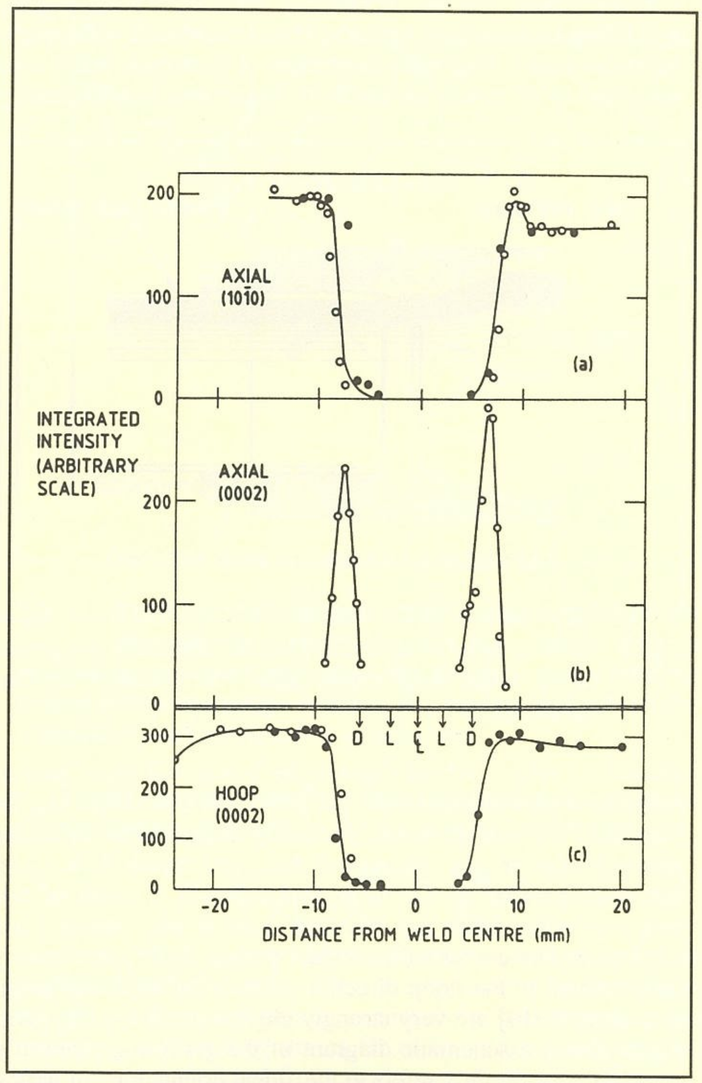

***Fig. 6** Integrated intensities of diffraction peaks determined in the measurement of axial, (a) and (b), and hoop strains (c) in a Zr-2.5Nb welded tube. The results for the as-welded tube are shown by open circles and after strain relief by closed circles. D refers to the edge of the oxidised zone and L to the edge of the lap mark.*

the strong axial $(10\bar{1}0)$ intensity begins to fall rapidly about 10 mm the weld centre, to a few percent of its original strength. The (0002) peak, normally weak in the axial direction, suddenly increases dramatically to a maximum 7 mm from the weld centre and then falls to zero. The drop in the (0002) peak in the hoop direction matches the drop of the $(10\bar{1}0)$ peak in the axial direction. These observations show that welding causes re-orientation of grains in the heat-affected zone as well as the melted zone. Of technical significance is the "ring" of grains with [0002] orientations aligned axially. The variation of the strains associated with these reflections is shown in Fig. 7. The biggest stress component in a tubular weldment is usually the tensile hoop component since the weld metal shrinks around the tube. The next largest component is expected to be axial tension at the inner surface of the tube. We observed tensile hoop strains approaching the weld with balancing hoop compressive strains beyond 15 mm from the centreline. Remember, however, that the number of grains with [0002] along the hoop direction is decreasing rapidly, because of grain re-orientation near the weld, so that (0002) may not be representative of the material behaviour in the hoop direction close to the weld. The axial strains as measured by $(10\bar{1}0)$ appear to become strongly compressive, running counter to our simple expectations. But the real problem is the tensile strain in the axial direction 7 mm from the weld centre shown by the axial (0002) measurements. The increased basal plane strain provides a natural location for zirconium hydride platelets to form in a hydrogen rich environment which

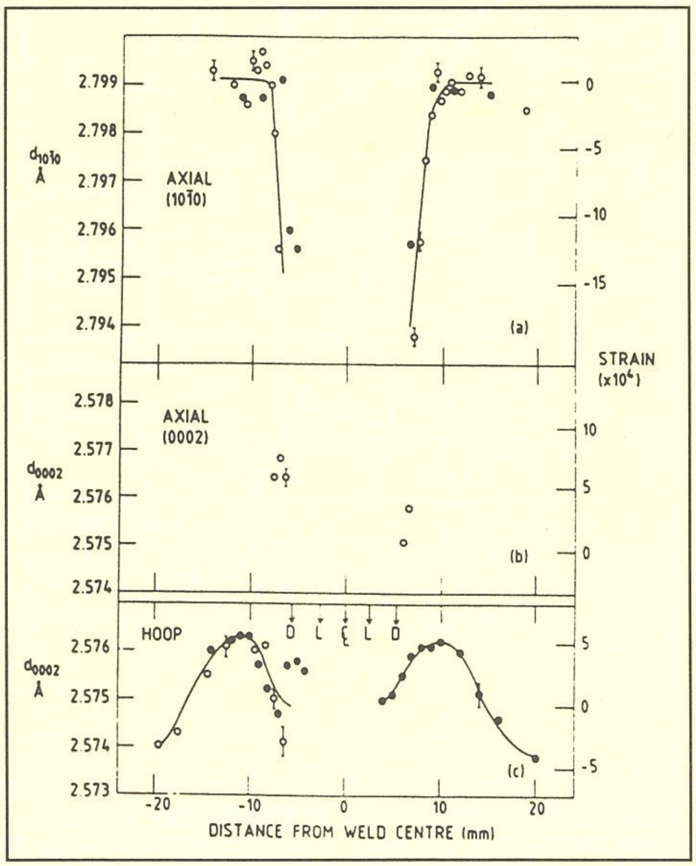

***Fig. 7** Residual strains in the axial direction, (a) and (b), and the hoop direction, (c), of a Zr-2.5Nb welded tube. Open circles denote the as-welded condition, and closed circles denote a strain relieved condition. The [0002] grains reoriented into the axial direction show large tensile effects.*

are oriented with the platelet normals nearly axial. Cracking of the platelets can cause guillotine failure. It is interesting to note that a stress-relieving heat treatment changes matters very little.

Similar work has been carried out on welds in zirconium plates[11] and on the effect of aging a weldment in a test loop in the NRU reactor. To do this latter experiment on a weldment emitting gamma radiation of 25R hr^{-1} on contact, it was necessary to build a special shield with 60 mm of lead encased in steel. Small windows through the lead annulus allowed the neutron beams to reach the weldment. The results on the aged weld as well as on a fresh weld, prepared in an identical fashion are shown in Fig. 8. The familiar hoop stress increase on approaching the weld-centre is observed. The slight differences between the irradiated and unirradiated welds are more likely to be due the variability between welds than the effect of aging at temperatures typical of an operating reactor, in the range 250°C to 300°C. The maximum residual hoop stress was observed to be 130 MPa which is much less than the 0.2% offset yield stress of the material.

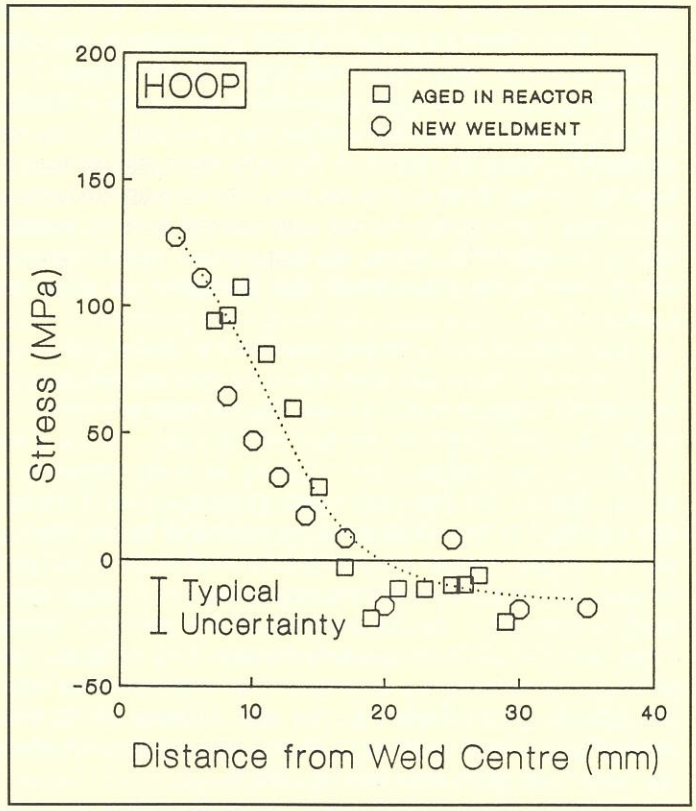

***Fig. 8** Hoop stress in aged and as-prepared Zircaloy-2 weldments.*

3.4 Residual Stresses in Steam Generator Tubing[12]

A major problem facing conventional as well as nuclear power generating stations is stress corrosion cracking in steam generator tubing. This occurs in regions of high stress at the apex of the bends in the tubing, at tube-to-tubesheet rolled joints or at points where the supporting structures touch and interfere with the tubes. In North America, the loss of revenue due to steam generator failures totals billions of dollars. If a tube has to be sealed to prevent leaks in a heat exchanger, this represents a straight loss of efficiency.

A bent tube is the analog of a plate with a permanent set bent beyond the yield point. The residual stress distribution, zigzag shaped, is calculated in elementary engineering textbooks. The dependent variable is the distance from the neutral axis, and this is equal to the sine function of the angle around the tube from the neutral axis multiplied by the tube radius. After forming the tube into a U-bend shape, residual stresses remain in the tube near the bend. These are undesirable because they may make the tube change shape in service, and make it prone to stress corrosion cracking if high tensile stress and a concentration of salts in an area of dryout coincide. Experiments on tubes are easy to perform and permit benchmarking between experiment and finite element analysis. The latter can then be confidently applied in geometries which are less accessible to experiment. A bent tube is expected to be an uniaxial stress system with the stress oriented along the tube axis.

The axial, hoop and radial strains in bent incoloy-800 steam-generator tube are shown in Fig. 9 as a function of the sine of the angle from the flank of the tube (the neutral axis). Measurements of strain were made in grains with [002], [111] and [220] crystallographic orientations along the axial, hoop and radial directions. The very surprising feature about Fig. 9 is that the axial residual strain for the [002] grain orientation is twice that for [111]. At the top of the bend, these two strains even have opposite signs. The hoop and radial strains for a given diffraction line are equal to each other within the uncertainty. They are reversed in sign with respect to the axial strain and reduced by a factor of about three so that the bent tube does approximate to an uniaxial stress system. Recent experimental work on Inconel-600 and Monel-400 tubes, all face-centred cubic materials, shows exactly the same trends and anomalies, so these are generic effects.

The macroscopic stresses calculated with the (002) and (111) strains with eq. (3) turn out to be positive and negative respectively at the apex of the bend. The macroscopic stress field cannot, by definition, be positive and negative in the same volume, so the stresses observed must be a superposition of type-II stresses, the grain interaction stresses, on some average stress field. The type-II stresses are generated by the bending process which, involves subjecting individual grains to different amounts of plastic deformation, depending on their crystallographic orientation. In the analysis of the problem, it was recognized that different grain-orientations had different yield points, corresponding to a common critical resolved shear stress, and that the strain hardening was also different. With these assumptions a semiquantitative theory was constructed which reproduced the main experimental effects.

Recently, these differences between the grains in polycrystalline Incoloy taken beyond the yield point, were explored in a series of tensile tests carried out on the diffractometer. The test samples were accorded a heat treatment similar to steam generator tubing and the microstructure was similar. Measurements were made of the total elastic plus plastic strain with an extensometer, and neutron elastic strain measurements were made with several diffraction peaks. The measurements were made as a function of stress above and below the 0.2% offset yield point, following several cycles of loading and unloading. The results for the longitudinal strain response for (111) and (002) peaks to a longitudinal stress are shown in fig. 10 and are most surprising. The (002) strain response beyond the yield point falls *below* the line of the stress-strain curve in the strictly elastic region. On unloading to zero stress from successively higher stresses, the residual strain in (002) grains becomes progressively more tensile. On the other hand, the (111) strain response beyond the yield point lies *above* the line of the stress-strain curve in the elastic region. On unloading from successively higher stresses, the residual strain in (111) grains becomes compressive. Thus uniaxial stress generates intergranular residual strains and stresses in a tensile test sample of a cubic metal when the 0.2% offset yield is exceeded even though there is no net stress on the sample after unloading. The most unexpected result is that the (111) grains behave as though they are deforming plastically and transferring load to the (002) grains which continue to deform elastically, and eventually sustain large residual effects.

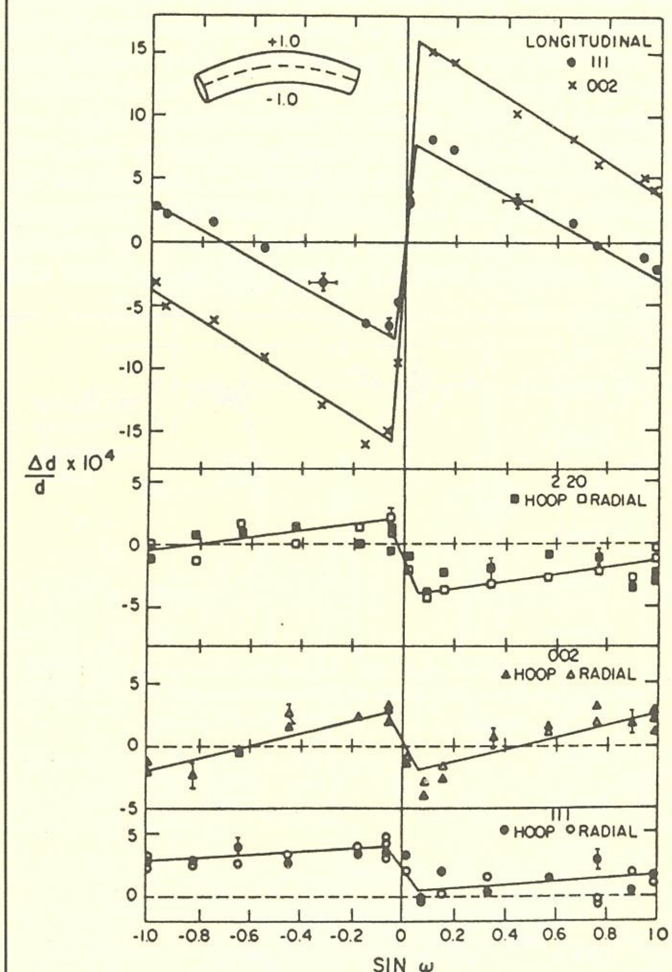

Fig. 9 ***Residual strains determined by neutron diffraction in the axial, hoop and radial directions in INCOLOY-800 bent tube vs the sine function of the angular position around the tube circumference. Large differences are observed between the strains measured with different reflections.***

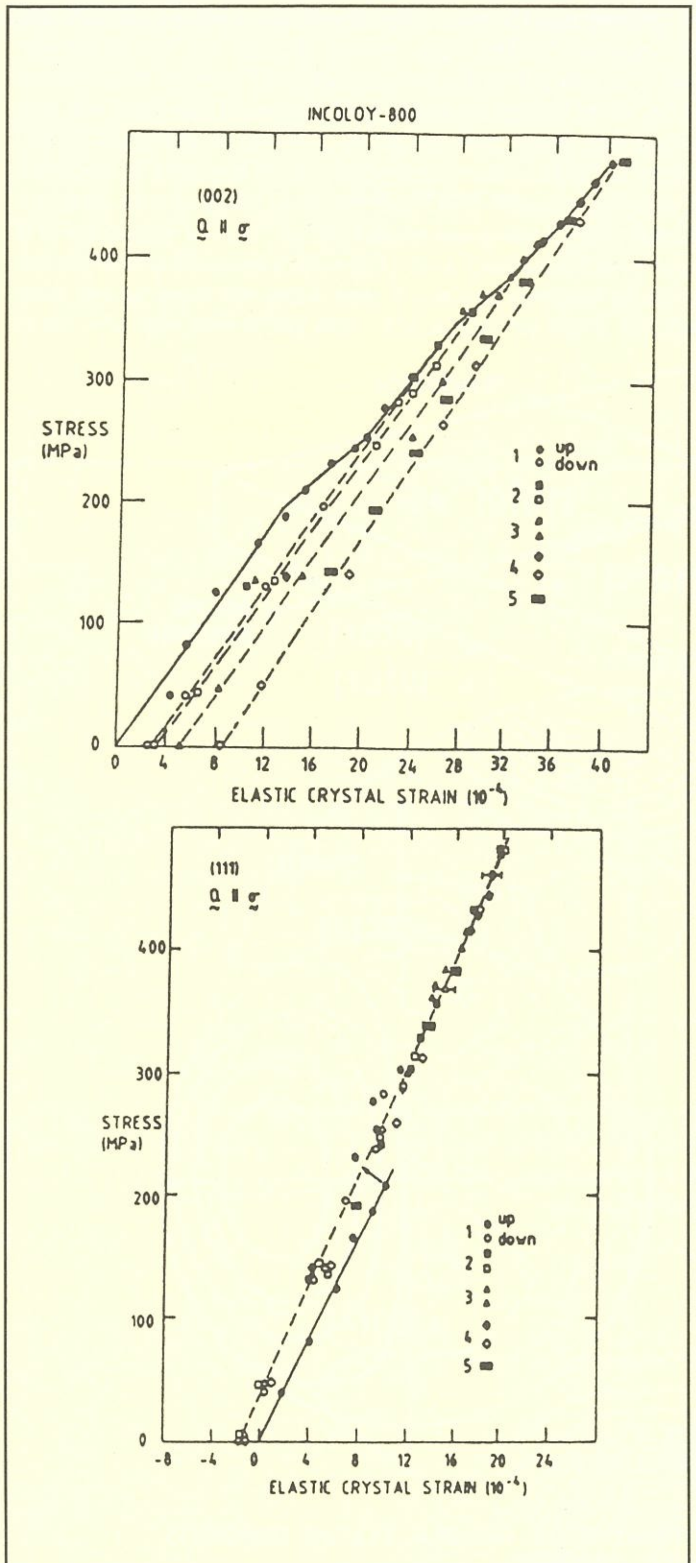

***Fig. 10** Axial strain response of the (111) and (002) planes of a polycrystalline tensile test sample of INCOLOY-800 to axial stresses greater than the 0.2% offset yield stress. Very different behaviour is exhibited by the two sets of grains. The (111) grains behave as though they are deforming plastically, transferring load to the (002) grains which continue to deform elastically.*

The residual strains in the bent Incoloy-800 tube for both (002) and (111) grains can be calculated from the response curves to stress. We calculate the bending moment for the U-bend operation and make the classical assumption that the tube unloads elastically. Since the U-bend process and the tensile test were both uniaxial no further information is required. The agreement between calculation and experiment is surprisingly good.

It was interesting to find that an urgent applied problem when thoroughly investigated gives a very good understanding of the more fundamental problem of the way residual stresses are generated in polycrystalline material. Deforming a metal beyond the yield point produces different stresses and strains in grains characterized by different crystallographic orientations. This is because of the different angles between the deforming stress axis and the slip directions in the slip plane for the different crystallite orientations. The tensile testing revealed just how the different orientations respond to applied stress.

3.5 Intergranular Stresses in Zirconium Alloys

Intergranular stresses, stresses on the scale of the grain size, are often ignored by engineers. However, taken with a high degree of crystallographic alignment they can strongly affect macroscopic properties. For example, the initial creep and growth transients of Zr-alloys in a fast-neutron flux depend on residual intergranular stresses.[13] The stresses arise in Zr-alloys because the plastic response beyond the yield point is strongly anisotropic, even more so than cubic materials discussed in the previous section, and because the coefficient of thermal expansion along the hexagonal axis is twice as large as it is perpendicular to the hexagonal axis. In zirconium alloys this means that large intergranular stresses will be generated when the material cools after annealing or thermal stress-relieving.

Usually crystallographic texture is considered a nuisance in stress measurements, but the very strong alignment of Zircaloy-2 or Zr-2.5Nb, offers the possibility of measuring complete strain tensors[14] for ideal orientations since there is a one-to-one correspondence between sample direction and crystallographic orientation. These strains are thermal strains caused by the higher thermal expansion in the [0002] direction than perpendicular to it. Fig. 11a shows a schematic view of the grain orientations in a 4.7 mm thick annealed Zircaloy-2 plate cold-rolled by 10% and given a four hour recrystallization anneal at 1070 K. The texture is such that there are two ideal orientations, labelled 1 and 2, defined to within about 15°. These have a common $[10\bar{1}0]$ direction along the rolling direction. The two hexagonal axis orientations, [0002], lie in the normal-transverse plane offset respectively ±40° from the plate normal. The Bragg peak intensities in the appropriate directions are about ten times brighter than they would be for a random orientation. The representation of intensity as a function of sample orientation is known as a pole figure and the $(10\bar{1}0)$ pole figure is shown in Fig. 12. Every region of high intensity was identified as belonging to one or other of the ideal orientations. It was a straightforward matter to align the sample on a goniometer so that the conditions for diffraction were fulfilled at the angular locations of the high intensity regions for the appropriate reflections. Since intergranular stresses are on the scale of the grain size, circular discs were cut from the zircaloy-2 plate without destroying the stresses, and these were aligned and assembled into a cylindrical sample of volume 2000 mm^3.

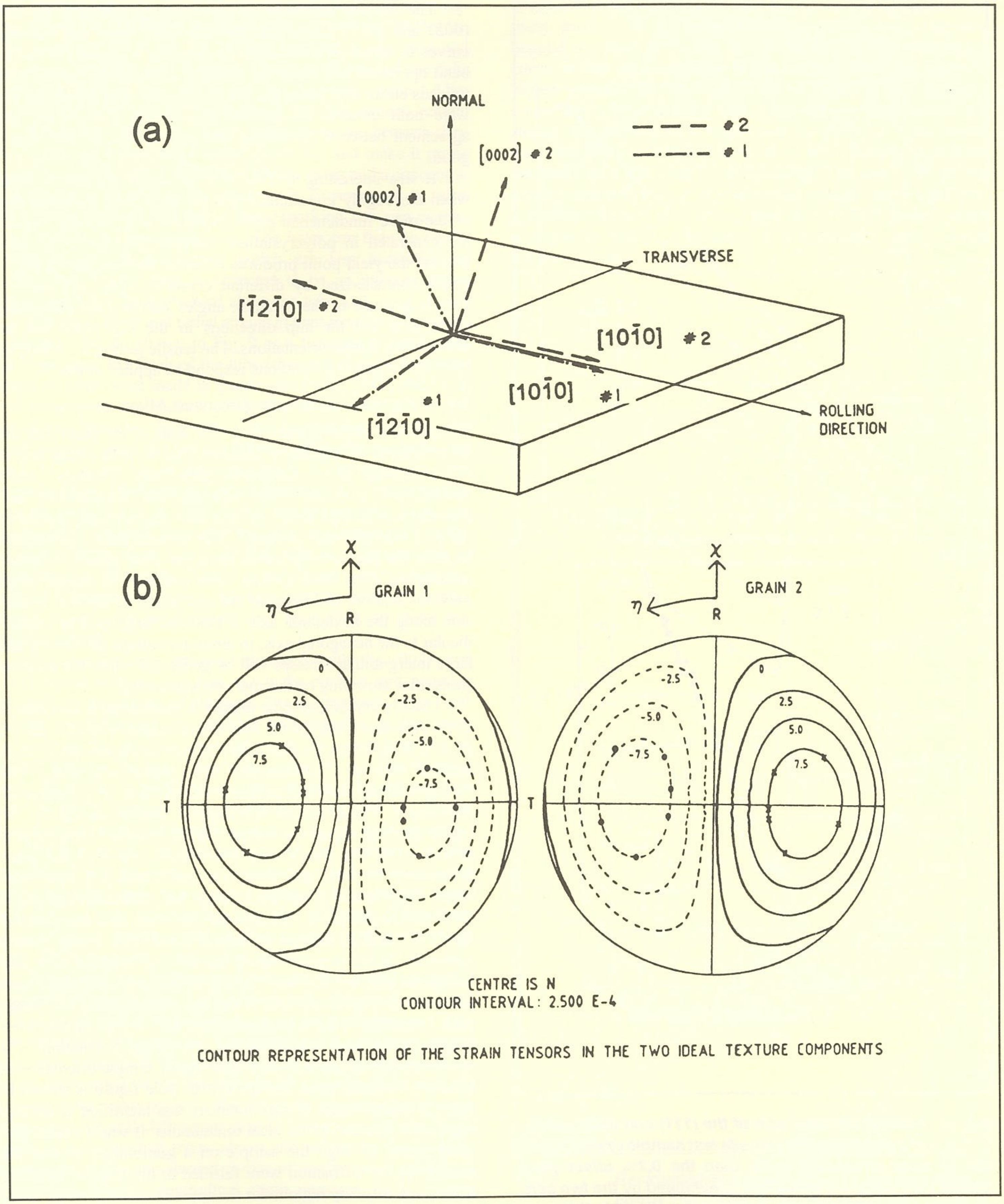

***Fig. 11** (a) Schematic representation of the grain orientation in Zircaloy-2 strip, cold-rolled by 10% and annealed.*
(b) Residual strain tensors observed for the ideal grain orientations plotted on a pole-figure contour format.

A pole figure representation of the strain tensor is shown in Fig. 11b for grains 1 and 2 with solid contours representing the magnitude of the tensile strains and dashed contours for compressive strains. An interesting aspect of the strains is that they are large but balanced. Thus the large tensile strain in the [0002] direction in grain 1, at about +40° from the normal direction, is balanced by the large compressive strain in nearly the same sample direction along the [$\bar{1}2\bar{1}0$] direction of grain 2. It is interesting to note that the strains along the rolling, normal and transverse directions are nearly zero. One would have been quite wrong about the stress state if one had confined attention to the principal axes of the plate. The reason for this is that the strains are locked into crystal orientations because of the way the individual crystals deform under load.

Progress in understanding the intergranular stresses and the effect of irradiation growth has been quite rapid in recent years with the advent of a self-consistent model of the strains which treats each grain as an elliptical inclusion in an average matrix.[15] Thermal strains and plastically induced strains can now be modelled satisfactorily from first principles. The models have been used to predict the growth behaviour of calandria tubes in a fast neutron flux, particularly the early transient behaviour and Fig. 13 shows that a good fundamental understanding is developing.

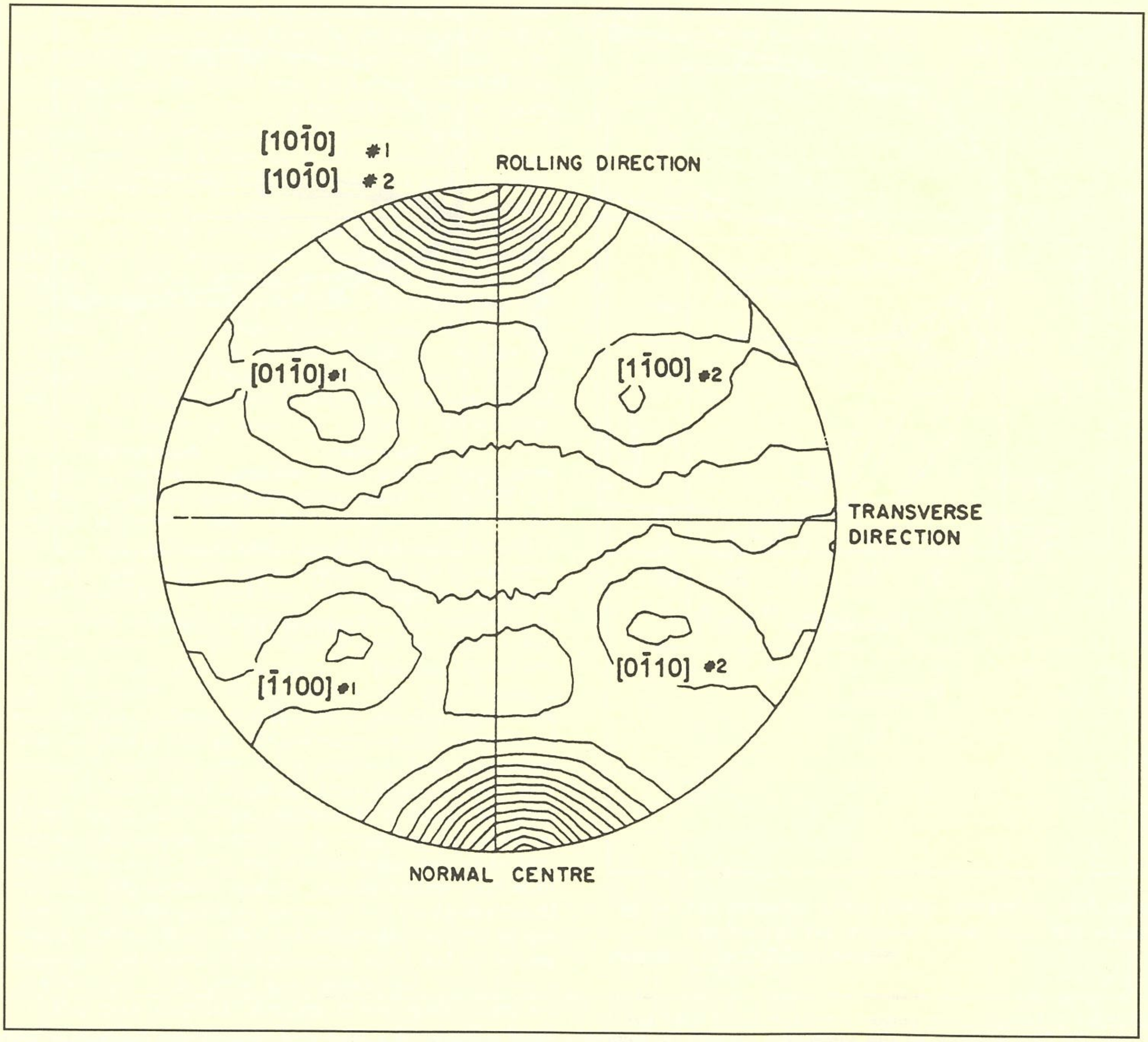

Fig. 12 (10$\bar{1}$0) pole figure for Zircaloy-2 strip, cold-rolled by 10% and annealed.

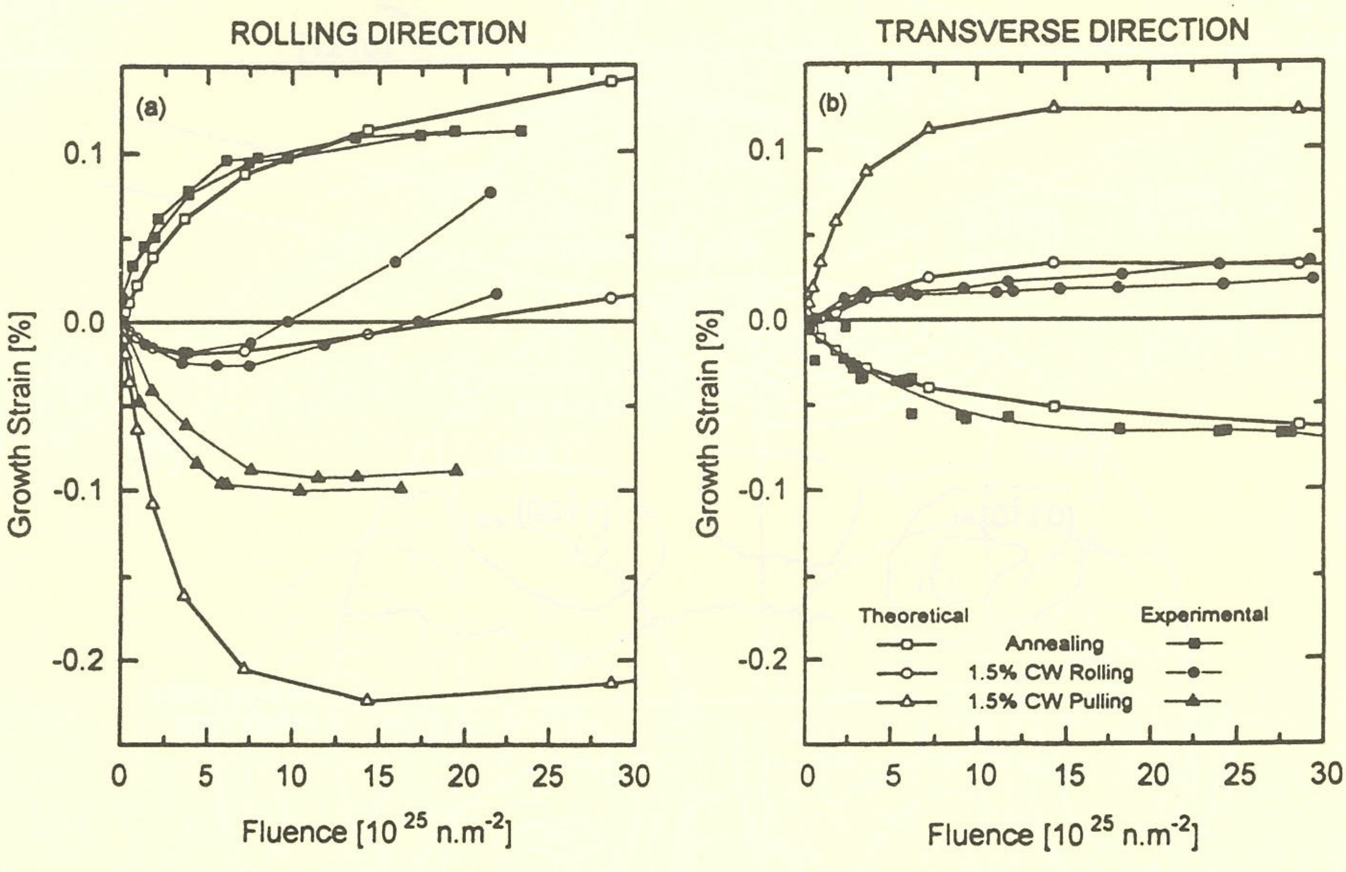

***Fig. 13** Calculations of the in-reactor growth of calandria tube material in a high fast-neutron flux compared with experiment. The calculations were based on the intergranular strain tensors derived from neutron diffraction. Theoretical results are represented by open symbols, experimental results by closed symbols. The curves are guides to the eye.*

3.6 Neutron Diffraction as a Probe of Microstructure

Neutrons are diffracted from crystal planes that are defined by Miller indices (*hkl*). However, the neutron beam is only diffracted from crystallites whose plane-normals, [*hkl*], are parallel to the scattering vector, which is the bisector of the incident and diffracted neutron beams. Only a subset of the grains within the volume is correctly oriented for diffraction to occur. The intensity of the neutron diffraction peak is directly proportional to the volume fraction of correctly oriented grains. This fact can be exploited to make neutron diffraction a probe of microstructure.

For example, suppose that the material is composed of grains with a completely random distribution of orientations. Diffraction peaks are measured by a detector that spans about 0.5° in the scattering plane and 2° vertically. Crystal plane-normals may point in any direction, not necessarily within the angular range subtended by the detector. In fact, when diffracting from the (200) peak in a cubic material, only about 1 in every 7000 grains is correctly oriented to scatter neutrons towards the detector. If the gauge volume is 1 mm^3, and the typical grain diameter is 50 μm, then, on average, only one grain contributes to the diffracted signal. However, at a given position of the gauge volume within the specimen, there is a reasonable probability that no grains are correctly oriented, or that two or more grains might be suitably oriented to scatter neutrons towards the detector. The measured intensity therefore fluctuates statistically, from zero to several times some mean value, on scanning the gauge volume from position to position within the engineering component. Similar intensity fluctuations would also be observed at a single position in a specimen that was rotated to place the scattering vector in a selection of specimen directions.

The fluctuations of intensity about a mean value, from position to position or from one orientation to another, are reduced when there are more grains contributing to the measurement. When N grains contribute to the measured intensity, the expected fluctuation is $\pm\sqrt{N}$. If the typical grain diameter was 10 μm, there would, on average, be 125 grains contributing to the measured intensity and the fluctuations in the measurement would be about 9% of the mean value. With an average grain diameter of 20 μm, the fluctuations would be about 25% of the mean value. By selecting a suitable gauge volume, and evaluating intensity fluctuations from position to position, the microstructural information of average grain size can be determined with reasonable precision over a wide range of values. However, this technique cannot stand alone because it is based on grain volume. Microscopy is required to determine the shapes of grains, such as the aspect ratios of the major axes. Only then, in a randomly textured material, can the volume fraction of correctly-oriented grains be converted into the dimensions of typical grains. When the crystallographic texture of the material is not random, further measurements and corrections must be made to determine grain dimensions.

The most complex situation occurs when there are variations of crystallographic texture from one position to the next in a specimen. At each position of the gauge volume, the crystallites have a local orientation distribution, with maximum (*hkl*) pole densities in particular specimen directions. The volume that encapsulates crystallites with a given orientation distribution is denoted as a texture zone. At another position in the specimen, the crystallites may belong to a new texture zone, where the pole-density maxima point in different specimen directions. Scanning the gauge volume from one position to the next, variations of diffraction intensity are observed as one moves from one texture zone to another. An example of this phenomenon in a Zr-2.5Nb sample is depicted in Fig. 14. In this figure, the intensity of the (0002) diffraction peak is measured as a function of direction, χ, which is the angle from the radial direction of the tube, towards the hoop direction. The χ-scans are shown at three positions, each separated by 2 mm in the hoop direction, and all 2 mm from the outer surface of the tube. The direction of the pole-density maximum shifts substantially over a small spatial displacement in the hoop direction, and texture zones can be identified.

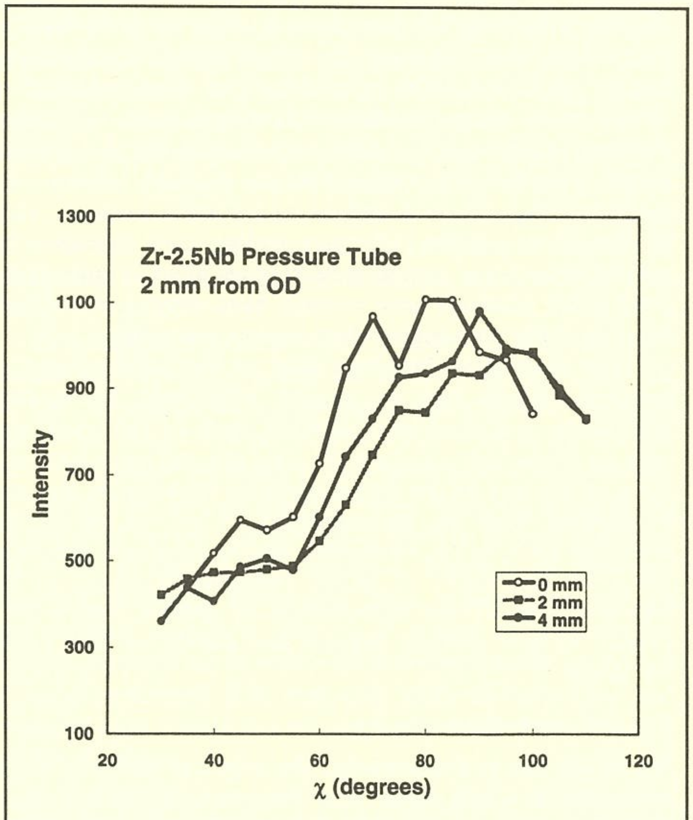

***Fig. 14** The intensity of the (0002) diffraction peak as a function of the angular offset from the radial direction in a Zr-2.5Nb sample.*

It has been found that some texture zones extend upwards of 10 mm in the axial direction of the sample. These zones may be vestiges of coarse body-centred cubic β-zirconium grains formed early in the fabrication process. The sample is made by a combination of forging, heat-treating and extrusion operations. The original β-grains are distorted by these operations, and transform into colonies of fine α-grains on cooling. Despite the deformation operations, each colony of α-grains may be oriented partially towards the original orientation of the parent β-grain, and each colony therefore forms a distinct texture zone. The phenomenon of "roping" a result of the formation of texture zones analogous to the effects we have observed in zirconium alloys has been observed previously in the formation of ferritic stainless-steel sheets.[16,17] Neutron diffraction scanning techniques are well-suited to map out the dimensions of texture zones, and to evaluate the effects of fabrication procedures on the development of texture zones in Zr alloy components.

4 Future Developments

We can confidently anticipate many future applications of the technique by improving the intensity of the neutron beams, and the efficiency of data collection, so as to be able to probe very small regions of critical interest to engineers. Small gauge volumes are needed for measurements of stresses near crack-tips which will then improve our understanding of fracture. Another area requiring the use of small gauge volumes is the region between 0.1 and 1.0 mm of a sample surface. Current surface modification methods, such as shot-peening, offer protection against crack formation by generating in-plane compressive stresses often of order of the yield point. Methods have recently been developed at Chalk River to probe this near-surface region accurately.

The cases described here give an idea of the scope of problems which can be tackled effectively by neutron diffraction. It is clear that industrial work of this nature not only demands high accuracy in lattice spacing measurements, but also requires all the crystallographic information that can be gleaned from the measurements. When we investigate problems such as the anomalous results for steam generator tubes we are forced to tackle fundamental issues in the understanding of the deformation of metals, which then impact on how residual stresses are understood throughout the world.

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Ed. Note: To augment the report by CNS co-chairman Alan Wight and to give readers some feel for the nature of the many excellent papers presented during the 16th Annual Conference of the Canadian Nuclear Society, following are selected abstracts from nine sessions as noted. The choice has been a subjective one by the editor.

Thermalhydraulics

MMOSS-I: A CANDU Multiple-Channel Thermosyphoning Flow Stability Model

by P. Gulshani, AECL and H. Huynh, Hydro Quebec

This paper presents a multiple-channel flow stability model, dubbed MMOSS, developed to predict the conditions for the onset of flow oscillations in a CANDU-type multiple-channel heat transport system under thermosyphoning conditions. The model generalizes that developed previously to account for the effects of any channel flow reversal.

Two-phase thermosyphoning conditions are predicted by thermalhydraulic codes for some postulated accident scenarios in CANDU. Two-phase thermosyphoning experiments in the multiple-channel RD-14M facility have indicated that pass-to-pass out-of-phase oscillations in the loop conditions caused the flow in some of the heated channels to undergo sustained reversal in direction. This channel flow reversal had significant effects on the channel and loop conditions.

It is, therefore, important to understand the nature of the oscillations and be able to predict the conditions for the onset of the oscillations or for stable flow in RD-14M and the reactor. For stable flow conditions, oscillation-induced channel flow reversal is not expected.

MMOSS was developed for a figure-of-eight system with any number of channels. The system characteristic equation was derived from a linearization of the conservation equations. In this paper, the MMOSS characteristic equation was solved for a system of N identical channel assemblies. The resulting model is called MMOSS-I. This simplification provides valuable physical insight and reasonably accurate results.

MMOSS-I predicts N modes of pass-to-pass out-of-phase oscillations. In only one of these modes, the total or thermosyphoning is oscillatory. In this mode, the flow oscillations in the channels in a given pass have all the same amplitude and phase. The amplitude of the oscillations decreases with the square root of the number of channels. Therefore, a system with a large number of channels (such as CANDU) is expected to be more stable than a system with a small number of channels (such as RD-14M). Therefore, a system with a large number of channels is less likely to exhibit channel flow reversal.

MMOSS-I and a previously-developed steady-state model THERMOSYPHON are used to predict thermosyphoning flow stability maps for RD-14M and the Gentilly 2 reactor.

Containment

Modelling of Reactor Air-Cooling Equipment Under Accident Conditions

by Sunil Nijhawan, Mir Consulting Inc.

Air-coolers are used as process and safety systems in containments of nuclear power plants. They are designed with comfortable margins and redundancy. Typically, they are operated to maintain the desired air temperature in their return air stream by modulating the cooling water flow.

In accident situations, the air cooler heat removal capacity can substantially increase under conditions of high moisture in the atmosphere. Cooler performance is not crucial in short term since the plants have other effective pressure suppression systems (e.g. vacuum or dousing). Only in later stages of accidents the coolers may not only become the dominant heat sink but they are also important for scrubbing suspended fission product aerosols from the containment atmosphere. An ability to produce best estimates of the air cooling equipment thermal loads is essential for predictions of boundary conditions used for the environmental qualifications of the nuclear plant equipment. This capacity is also needed for realistic assessments of accidents.

This paper describes an analytical methodology for prediction of heat and fission product removal capacity of an air cooler under a wide range of local environments. It can be used to interface with larger safety analysis codes, or as a self-standing tool. Since prediction of condensation rates from air streams with varying compositions of steam and non-condensables cannot avoid some uncertainties, the model is designed to be flexible and allow parametric analyses. A number of correlations and various analytical choices are available to the user.

The stand-alone code AIRCOOL is described in this paper. It models the thermal response for finned tube and plate air coolers. The predictions are compared against available data for various air coolers. In addition to equipment specific geometric parameters, major independent variables are the air composition, air temperature and the cooling water flow and temperature. Various phenomena such as potential flooding of finned surfaces and effect of fouling are examined. Methods of obtaining important geometric parameters from cooler drawings are demonstrated. Sensitivity analysis to a host of condensation models, and presence of additional non-condensable gases such as H_2 is performed. The analytical methods assembled and employed in this study can be adapted to assess behaviour in a variety of coolers.

Control and Instrumentation

The Human Factors Engineering Program Plan

by J. Jamieson, AECL CANDU, Saskatchewan

Operating AECL CANDU reactors have received world-wide recognition for their exceptional plant safety and performance record. The evolutionary design of AECL's next generation CANDU nuclear power station, at the new AECL CANDU design centre in Saskatoon, Saskatchewan, will further enhance this performance. Plant safety and human performance improvements are major goals for this design.

The estimated contribution of the human component to the world-wide reportable Nuclear Power Plant system failures is 70%. The emerging premise is that it is not possible to directly observe many of these "plant safety" related failures during stages of detailed design. Whereas traditional Human Factors

Engineering (HFE) activities have concentrated primarily on detailed design areas, modern day HFE activities need to be broadened and assimilated into the entire design process. Designing, in a manner which increases both human performance and plant tolerance to inappropriate human actions, requires HFE involvement from early design stages.

Findings from the International Atomic Energy Agency are in support of these design initiatives. They cite that a great number of abnormal events, both minor incidents and serious accidents, are attributed to inappropriate human actions. These actions are frequently due to a lack of awareness regarding the safety significances of plant conditions, a violation of procedures, mis-information, inappropriate mindset, training, or insufficient skill base. To ensure plant safety, the IAEA recommends a "defense in depth" strategy. This implies the use of a number of barriers to prevent the occurrence of an event. Human Factors design is such a barrier. The IAEA believes a Human Factors design program will improve the integrity of the Human Factors barrier. They believe a Human Factors design program will result in a design which has reduced human error, facilitates corrective human decisions, precludes incorrect human decisions, and provides detection and defense against inappropriate human actions. The Nuclear Regulatory agencies are also in support of a Human Factors design program and have incorporated it as a mandatory requirement.

AECL has adopted this progressive attitude towards the widening role of HFE in the design process for the evolutionary design of its next generation CANDU products. The Human Factors Engineering Program Plan provides evidence of this and formally establishes an HFE defense in depth strategy.

This paper will address the purpose of the Human Factors Engineering Program Plan (HFEPP), the resources required, the technical program and HFE activities, and the processes and procedures ensuring proper implementation. The HFEPP for the CANDU 3 control centre design program will be discussed as an illustrative example.

Engineering and Maintenance

Auto-Lay: Automatic Layout Generation for Procedure Flow Diagrams

by P. Forzano, P. Castagna, Ansaldo – Un'Azienda Finmeccanica, Italy

Nuclear Power Plant Procedures can be seen from essentially two viewpoints: the process and the information management.

From the first point of view, it is important to supply the knowledge apt to solve problems connected with the control of the process, from the second one the focus of attention is on the knowledge representation, its structure, elicitation and maintenance, formal quality assurance.

These two aspects of procedure representation can be considered and solved separately. In particular, methodological, formal and management issues require long and tedious activities, that in most cases constitute a great barrier for procedures development and upgrade. To solve these problems, Ansaldo is developing DIAM, a wide integrated tool for procedure management, to support in procedure writing, updating, usage and documentation.

One of the most challenging features of DIAM is AUTO-LAY, a CASE subtool that, in a complete automatical way, structures parts or complete flow diagrams. This is a feature that is partially present in some other CASE products that, anyway, do not allow complex graph handling and isomorphism between video and paper representation.

AUTO-LAY has the unique prerogative to draw graphs of any complexity, to section them in pages, and to automatically compose a document. This has been recognized in the literature as the most important second-generation CASE improvement.

Safety and Licensing

The Fuel String Relocation Effect – Why the Bruce Reactors Were Derated

by M. Gold, M.Z. Farooqui, A.S. Adebiyi, R.Y. Chu, N.T. Le and A.F. Oliva, Reactor Safety and Operational Analysis Department; G. Balog and T. Qu, Bruce NGS B Nuclear Safety Department; and P.G. deBuda, Darlington NGS Nuclear Safety Department; Ontario Hydro.

In the CANDU Safety Analysis process, a series of design basis accidents are chosen and analyzed to confirm safety system effectiveness. Of all the postulated accidents, the Large Break Loss of Coolant Accident (LBLOCA) – a postulated break in the Heat Transport System piping near a component that services a large number of fuel channels – sets the most demanding requirements on the speed and reactivity depth of the shutdown system devices – shutoff rods and liquid poison injection. In such an accident, coolant discharges out of the fuel channels, leading to a reactivity increase and power increase, turned around by shutdown system action within seconds. While the event is extremely improbable, it is reanalyzed periodically and its consequences examined to ensure continued shutdown system effectiveness.

In March 1993, an additional effect was identified: if the break occurred in the piping on the inlet side of the core, this would cause sudden movement of the fuel bundles (so-called *fuel string relocation*) in a large number of channels. In Ontario Hydro's Bruce NGS A, Bruce NGS B and Darlington reactors, each channel is fuelled against the flow. In this situation, the relocation of the fuel string results in a sudden positive reactivity increase. (By comparison, Ontario Hydro's Pickering A and Pickering B reactors, and the CANDU-6 reactors at Point Lepreau, Gentilly and overseas, are all fuelled *with* the flow rather than *against* the flow, so that the fuel string relocation results in a negative reactivity pulse.)

This reactivity increase is in addition to the reactivity due to the core coolant voiding. The combined reactivity effect could lead to power pulses much higher than those that would arise due to coolant voiding alone. To maintain safety margins in the event of such a postulated accident, the eight Bruce NGS A and Bruce NGS B units were initially derated to 60 per cent power within 2 days of the identification and confirmation of this effect.

This paper: (1) describes the fuel string relocation phenomenon in detail; (2) explains why the consequences differ at the various Ontario Hydro reactors; (3) outlines the actions taken with respect to each of the Ontario Hydro reactors in the months following March 1993; (4) describes the design solutions implemented to mitigate the problem and return the Bruce reactors to higher powers.

Severe Accidents and PSA

Results of the CANDU 3 Probabilistic Safety Assessment

by R.K. Jaitly, AECL CANDU, Saskatchewan

The CANDU 3 is one of the next generation models of the CANDU reactors. It provides the economy of operation of other CANDUs in a smaller unit size (450 MW). The design makes use of proven technology from the larger CANDU units along with updated relevant features from ongoing Canadian research and development. A key part of the CANDU 3 design program is a review of the design by the Canadian regulatory agency (AECB) prior to the start of construction. These up front licensing discussions provide an opportunity for the AECB and industry to explore and resolve the main issues during the design stage. Including Probabilistic Safety Assessment (PSA) as part of the design process was seen as one valuable way of ensuring that safety related requirements are defined early. These measures minimize the probability of engineering rework during and after plant construction. In addition the PSA is being used in the traditional role in safety assessment and licensing. This paper provides a summary of the CANDU 3 PSA work and the results thereof.

New Applications

Fuel Alternatives for Oil Sands Development – the Nuclear Option

by David Bock, AECL CANDU, and John K. Donnelly, Independent Consultant

Currently natural gas is the fuel of choice in all oil sand developments. A reservoir screening study was conducted to determine the magnitude of the bitumen resource which can be economically exploited using the Steam Assisted Gravity Drainage (SAGD) technology. The study indicates that there are a total of twenty-eight Townships in the Athabasca area where each SAGD well pair (800 metres long, 90 metres spacing) could be expected to produce an average of at least 625 (100 m^3) barrels of bitumen per day, over five years, at a cumulative steam oil ratio (CSOR) of 2.5 m^3/m^3 or less. This suggests that at least 28 commercial recovery projects could be supported, each potentially producing at least 130,000 barrels (20,600 m^3) of bitumen per day for 30 years. Some townships could be capable of supporting projects two to three times as large. The twenty-eight, 30 year SAGD recovery schemes would produce a total of at least 40 billion barrels (6.35×10^9 m^3) of bitumen. This is approximately 12% of the total Athabasca reserves deemed recoverable by SAGD. At a CSOR of 2.5 m^3/m^3, more than 42 EJ of energy would be needed to generate the required steam. An additional 42 EJ of natural gas would be required to produce the hydrogen required for high conversion upgrading the produced bitumen to synthetic crude oil (SCO). The combined requirements for steam generation and hydrogen production is 60 per cent of the remaining ultimate potential of natural gas in Alberta. Clearly fuels other than natural gas must be used if the full potential of oil sands is to be realized. Alternate fuels which are in sufficient supply to have a significant impact on the energy requirements for oil sands development are nuclear energy and those derived from bitumen and coal. The Alberta sources of hydrocarbon based fuels are large but limited.

Canadian nuclear technology was studied as a possible alternative for providing steam for the deep commercial in situ oil sand projects which were initiated over ten years ago. Because the in situ technology of that time required steam at pressures in excess of 10 MPa, the nuclear option required the development of new reactor technology or the use of steam compressors which was not economical. The current SAGD technology requires steam at pressures of less than 5 MPa which is in the reach of existing Canadian nuclear technology.

The cost of supplying steam for a SAGD in situ project using a CANDU 3 nuclear reactor were developed. The study indicates that for gas prices in excess of $2.50 per gigajoule, replacing natural gas fuel with a nuclear reactor is economically feasible for in situ projects in excess of 123,000 barrels per day.

Radiation

Developments in Biological Dosimetry for the Nuclear Industry

by K.L. Gale, D.R. Boreham, S. Maves and D.P. Morrison, AECL Chalk River Laboratories

The purpose of this program is to develop methods for providing estimates of radiation exposure based on changes in the cells/tissues of exposed individuals. This work arises from the need for independent measures of exposure of workers when standard dose measurements are unavailable or questionable. The radiation-induced changes that we propose to measure have been correlated with carcinogenesis. It follows that the methods used should also provide indications of the likely biological consequences of radiation exposure for an individual. The consequences of radiation exposure lie in the resolution of the radiation effects at the cellular level. Accordingly, it is at the cellular level that our attention is directed. More precisely, since the consequences of most concern, cancer induction and the induction of inherited diseases, are the results of changes to the genetic material of cells (the DNA), it is the measurement of effects on DNA that are being investigated as possible dose meters. Individuals are unique in terms of their DNA and differ in their cellular capacities to repair the damage from an ionizing radiation dose. Because of these features, not only do biological dosimetry tools offer us a means of measuring a dose at the individual level but may also provide us with a measure of the ultimate risk associated with a given exposure.

Computers

Determining the Confidence Levels of Sensor Outputs using Neural Networks

by Gregory S. Broten and H.C. Wood

This paper describes an approach for determining the confidence level of a sensor output using multi-sensor arrays, sensor fusion and artificial neural networks. The authors have shown in previous work that sensor fusion and artificial neural networks can be used to learn that relationships between the outputs of an array of simulated partially selective sensors and the individual analyte concentrations in a mixture of analytes.

Other researchers have shown that an array of partially selective sensors can be used to determine the individual gas concentrations in a gaseous mixture.

The research reported in this paper shows that it is possible to extract confidence level information from an array of partially selective sensors using artificial neural networks. The confidence level of a sensor output is defined as a numeric value, ranging from 0% to 100%, that indicates the confidence associated with an output of a given sensor. A three layer back-propagation neural network was trained on a subset of the sensor confidence level space, and was tested for its ability to generalize, where the confidence level space is defined as all possible deviations from the correct sensor output. A learning rate of 0.1 was used and no momentum terms were used in the neural network.

This research has shown that an artificial neural network can be accurately estimate the confidence level of individual sensors in an array of partially selective sensors. This research has also shown that the neural network's ability to determine the confidence level is influenced by the complexity of the sensor's response and that the neural network is able to estimate the confidence levels even if more than one sensor is in error.

The fundamentals behind this research could be applied to other configurations besides arrays of partially selective sensors, such as an array of sensors separated spatially. An example of such a configuration could be an array of temperature sensors in a tank that is not in equilibrium. Hence each sensor represents a sample which contributes information about the process in the tank.

COG / AECB Agreement

For the first time representatives of the Atomic Energy Control Board attended the annual Safety and Licensing Research and Development Seminar held by the CANDU Owners Group held the end of May in Toronto. Dr. Jatin Nathwani, COG program manager and chairman of the Seminar, announced that an agreement had been reached with the AECB only days previously. He noted that the COG Safety and Licensing program "continues to be driven by the immediate needs of the licensing process."

Nathwani gave the following three objectives of the COG/AECB Information Exchange Agreement:

- to allow AECB staff to gain a fuller understanding of the nature and extent of the COG safety and licensing R and D program;
- to inform COG members about emerging AECB staff positions that may impact on the safety and licensing R and D program;
- to facilitate timely discussion of new research findings and possible impact on future directions.

He added that the Agreement was founded on three principles:

- licensees are responsible for reactor safety and hence for integration of R and D results into licensing submissions;
- communication among participants will be open, constructive and concentrate on facts;
- interactions under the communications protocol are intended for the exchange of R and D information from the COG safety and licensing program and the AECB research program relevant to the resolution of reactor safety issues.

The Communication Protocol envisions communication at three levels: formal, corporate positions through established channels; meetings or communications arranged by the primary contacts of COG (Nathwani) and AECB (to be announced); informal communications between AECB staff, licensee staff, and researchers.

The Agreement is for a "trial" period of two years.

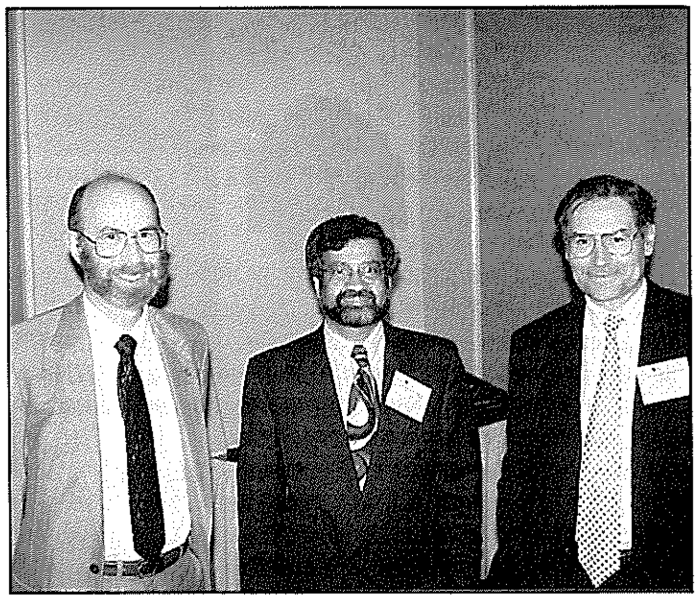
Nathwani commented that there was already a "truckload of documents" on its way to the AECB.

Despite the new agreement the tone and content of the talk by John Waddington, AECB director general, caused some to wonder if there had been any progress in meeting AECB wishes. Waddington recited a number of "outstanding CANDU safety issues" taken from the AECB's list: ECC performance; single channel failure; core cooling without forced flow; pressure tube ballooning; hydrogen in the containment; pressure tube failure.

In each case his evaluation of the state of understanding or resolution of the issue was "not sure." He reminded those attending that theses issues had been around for years. Quoting AECB president, Dr. Agnes Bishop, that the AECB would not license on promises, Waddington warned that they will expect all of these issues to be dealt with in the CANDU 9 design.

During the question period, when asked if AECB would follow the USNRC towards "risk based regulation" Waddington stated that AECB was looking at how it could use probabilistic safety analyses to help determine priorities and criteria.

Members of the audience commented that there needs to be consistency throughout the AECB. Others suggested that there must come a point when the AECB agrees that sufficient knowledge is available to show that the residual risk is acceptably small. Waddington's response was that they were always willing to discuss.



Flanked by two of the principal speakers, Jatin Nathwani, chairman of the COG Safety and Licensing R and D Seminar, held in Toronto in late May, is shown with Victor Snell of AECL and John Waddington of AECB.

COG Safety and Licensing Research and Development Program

***Ed. Note:** the following is drawn from the opening address by Dr. Jatin Nathwani, program manger, at the 1995 Annual Seminar of the CANDU Owners Group Safety and Licensing Research and Development Program, held in Toronto the end of May.*

The research and development effort of the CANDU Owners Group is divided into five programs. Each is overseen by a technical committee (except "CANDU technology" which has three). The COG organization also has an offices for information exchange and an adminstration group.

The five research and development areas and their 1995 budget (in millions of dollars) are:

- safety and licensing 37
- fuel channels 35.5
- CANDU technology 48
- waste management 36
- health and safety 13.5

Reflecting cutbacks everywhere the COG Safety and Licensing research and development budget for 1995/96 is 8% lower than last year.

The mission statement of the Safety and Licensing program is:

To advance the technologies basic to the resolution of issues in nuclear safety and licensing.

This is augmented by the following goal statements:

- *Verify the safety design bases and the safe operating envelopes for operating stations;*
- *Resolve outstanding licensing and safety issues;*
- *Support safety assessment for new plant designs and concepts;*
- *Maintain the capabilities and infrastructure necessary for a safety research and development program.*

The rationale for these statements is given as:

- **safety is the primary thrust**
  – operational experience and ageing give rise to new safety concerns
- **protection of investment**
  – to maintain integrity of systems and components for safe operation to the end of life
- **licensing**
  – licensing requirements continue to evolve - utilities need support in the licensing process – the confidence of the regulator must be gained.

Ten topical areas are included in the program:

- **fuel high temperature transients**
  – experimental data to confirm understanding of the behaviour of fuel and fission products during an accident typical of LOCA/LOECI conditions
- **fuel technology**
  – improve the performance and the CHF margin of CANDU fuel. Strengthen the technical responses capability for station acute events. Perform fundamental studies on the behaviour of extended burn-up fuel
- **fuel channel high temperature transients**
  – determination of channel behaviour and integrity under high temperature transient conditions
- **containment**
  – demonstration that containment system design is adequate to limit accident consequences
- **safety thermalhydraulics**
  – data to support improved understanding of the CANDU system thermalhydraulic behaviour under upset and accident conditions
- **fuel channel critical power ratio**
  – thermalhydraulic data, correlation and codes for improved operation of existing reactors and for licensing activities for both existing and new reactors
- **pressure tube failure consequences**
  – to quantify the consequences of pressure tube failure under normal operating conditions and establish the damage potential to in-core structure
- **moderator circulation experiments**
  – to maintain and/or relax operating limits on moderator outlet temperature and to improve plant performance by avoiding derating
- **radiation and reactor physics**
  – to provide, maintain and validate up-to-date computer code and data bases for reactor and radiation physics analysis of CANDU reactors
- **codes and modelling**
  – develop and validate that CATHENA and CANSIM computer codes for best-estimate analysis of CANDU fuel, fuel channel and system thermalhydarulc behaviour. Assess ASSERT-IV capability for CCP calculations.

As well as its extensive work in Canada COG participates in several international cooperative programs, with CEA and ISPN in France; GRS in Germany; USNRC; RASPLAV in Russia, NUPEC in Japan; and Belgo Nuclear High Burnup Chemistry Club in Belgium.

A COG Safety and Licensing R and D Program strategic plan has been developed and issued in a separate document.

Further information on COG can be obtained from: CANDU Owners Group, 700 University Avenue, H13, Toronto, Ontario, M5G 1X6.

Call for Papers
Chemical and Nuclear Engineering Symposium
of the
46th Canadian Chemical Engineering Conference
Kingston, Ontario
29 September to 2 October 1996

For information contact:
Dr. C. C. Hsu or E. W. Grandmaison
Technical Program co-chairmen
Department of Chemical Engineering
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Kingston, Ontario K7L 3N6

UNB Signs Accords with Russian Institutes

The University of New Brunswick signed two agreements with Russian nuclear institutes in early June.

The accords were formalized during the visit of Alexander Brioussov and Valeri Balanda of the Institute of Physics and Power Engineering (IPPE) in Obninsk to UNB. Hosting the visit and signing on behalf of UNB was Dr. Derek Lister, holder of the Industrial Research Chair in Nuclear Engineering funded by NSERC, NB Power and AECL.

One agreement is between UNB and the Institute of Nuclear Power Engineering, also in Obninsk, for overall co-operation in the areas of training and teaching which Lister noted opens up the possibility of exchanges among faculty, staff and students.

The other agreement is between UNB and IPPE for co-operation in the area of nuclear research and related topics.

While in New Brunswick the Russian scientists visited the Point Lepreau nuclear power station. Afterwards they went on to the Chalk River Laboratories and Mississauga offices of AECL.

The visit was sponsored by the Association of Universities and Colleges of Canada.

Two nuclear scientists from Russia recently visited the University of New Brunswick in Fredericton to forge research and educational links. Reviewing a co-operation agreement are, seated from left, Alexander Brioussov of the Institute of Physics and Power Engineering in Obninsk, Russia; and Frank Wilson, UNB' vice-president (research and international co-operation). Standing, from left, are Valeri Balanda, also of the Russian institute, with UNB's international liaison officer, Christiane Paponnet-Cantat; and holder of the industrial research chair in nuclear engineering, Derek Lister. (photo courtesy Joy Cummings).

McMaster Reactor to be Shut Down

The governing bodies of McMaster University have decided to shut down the 35 year old McMaster Nuclear Reactor next January.

An internal task force that studied the situation concluded that the university could not justify the $1.3 million annual cost of operating the research reactor. Federal government support ended in 1991. Since then McMaster attempted to offset some of the operating costs through the production of radioisotopes for the pharmaceutical industry and other revenue generating activities. While reasonably successful the revenues were not sufficient.

Dr. Martin Taylor, acting vice-president, research, noted that the use of the reactor for research had declined in recent years.

Decommissioning is scheduled to begin 15 January 1996. Until then the reactor will continue to operate normally. The decommissioning process could take up to three years.

Closing of the reactor will mean the eventual loss of 13 full-time positions.

News from Ontario Hydro

by Ric Fluke

Ontario Hydro appoints new Executive Vice-President

Ontario Hydro President Allan Kupcis, on April 19, 1995, announced the appointment of George Hugh as Executive Vice-President and Managing Director of the Generation Business Group, effective June 1, 1995.

Hugh has extensive national and international experience in the energy service sector, culminating most recently with his position as Chief Operating Officer of TransCanada PipeLines Limited where he was responsible for all operations and engineering of the natural gas multinational.

His varied background includes an MBA from York University in Toronto, and an engineering degree in Mechanical/Nuclear Engineering from the United Kingdom.

"As Executive Vice-President and Managing Director of the Generation Business Group, George will be responsible for the smooth operation of the generation businesses while, at the executive level, contributing to the strategic issues facing Ontario Hydro as the competitive marketplace evolves," said Kupcis.

Don Anderson to retire

Don Anderson, General Manager of Ontario Hydro Nuclear, announced on June 29, 1995, that he will retire from Ontario Hydro, effective September 30, 1995. Don will be leaving the company after 32 years of distinguished service. His most recent accomplishments include the successful completion of Darlington and the creation of OHN as a viable, competitive business. He is leaving OHN at a point when the Leadership Team feels OHN has become stronger than ever and has an assured future. Members of the Leadership Team thank Don for leading OHN and putting it on a successful track.

Bruce Unit 2 Lay-up

Preparations have begun for the "lay-up" of unit 2 at Bruce Nuclear Generating Station A.

Unit 2 is not scheduled to shutdown until July or September of this year, but preparations are being made to ensure that the unit will be safely shutdown and put it in a preserved state so that the equipment does not deteriorate over the lay-up period. The planning assumption is that the lay-up period will be five years, with up to three years to make a decision on whether to return the unit to service and another two to replace the boilers, retube and rehabilitate the unit.

An Engineering Assessment Team has been set up to examine the issues and develop specifications. Experience from Hydro's thermal stations, Pickering retube, U.S. utilities and the chemical industry in general is being consulted.

The unit will be isolated from containment, and the fuel and boosters will be removed, and all the major systems such as the Heat Transport, the Moderator and the Steam and Feed Systems will be drained, dried and left with some kind of dry purge on them. The boilers, however, must be replaced (which is the primary reason for the shutdown) and so there will be no attempt to preserve them.

19th Nuclear Simulation Symposium
Hamilton, Ontario
15 – 17 October 1995

This symposium covers all aspects of nuclear modelling and simulation including thermalhydraulics, reactor physics and safety analyses. The main objective is to provide a forum for discussions and exchange of views amongst scientists and engineers working in the nuclear industry.

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CNS Honours and Awards for 1995

Each year the Canadian Nuclear society presents awards to individuals and teams to recognize their contributions and achievements.

The awards for 1995 were presented during the CNS luncheon held June 7 during the CNA/CNS Annual Conference in Saskatoon. In the absence of Honours and Awards chairman Bill Midvidy the awards were presented by former president Paul Fehrenbach, a member of the committee.

A new award was created this year "for outstanding **team** achievements in the introduction or implementation of new concepts or the attainment of difficult goals in the nuclear field in Canada." Following the untimely death in April of Dr. John Hewitt, one of the founders of the Society and its third president, the award was named the **John S. Hewitt Team Achievement Award.**

As well as that award, three members were named as **Fellows of the Canadian Nuclear Society.**

The **Innovative Achievement Award** was not presented this year due to a lack of suitable nominations.

Following are the citations read out by Paul Fehrenbach.

John S. Hewitt Team Achievement Award

The winners of the 1995 **John S. Hewitt Team Achievement Award** are being recognized for the original development and demonstration of the technology for the dry storage of used CANDU fuel in concrete canisters, which was carried out at the Whiteshell Laboratories of AECL. This technology has subsequently been engineered into several successful products which have been implemented at a number of CANDU power stations and has been instrumental in increasing the lifetime of underwater spent fuel storage facilities and providing the capability for safe storage of spent CANDU fuel until a disposal repository is available.

Two of the three winners of the 1995 CNS John S. Hewitt Team Achievement Award, Bill Morgan and Mitch Ohta, pose with 1994-95 president Ed Price. Missing is Don McLean.

The 1995 winners of the first John S. Hewitt Team Achievement Awards are **Mr. Bill Morgan, Mr. Don McLean, and Mr. Mitch Ohta.**

CNS Fellowship Awards

The membership category of **Fellow of the Canadian Nuclear Society** was established in 1992. The criteria for admission include "major and sustained contributions to the sciences and/or professions that relate to the advancement of nuclear technology in Canada." Demonstrated maturity of judgement, breadth of experience, outstanding technical capability and service to the Canadian Nuclear Society are also requirements for admission.

In the tradition of learned societies CNS Fellows are entitled to add the letters "F.C.N.S." to letters donating degrees and professional certifications following their names.

This year three members are being honoured.

Michel Ross

Michel Ross receives certificate from 1994-95 President Ed Price as he becomes Fellow of CNS

The first of the 1995 CNS Fellows is being recognized for engineering and management contributions to the commissioning and decommissioning of the Gentilly 1 reactor in Quebec, for technical leadership and management of the very successful commissioning and subsequent operation of the Gentilly 2 reactor, for continuing activities in helping to maintain the nuclear option alive within Hydro Quebec, and for an active role in the activities of the Quebec Branch of Canadian Nuclear Society. We welcome Mr. Michel Ross, senior nuclear advisor for the Nuclear Management Directorate of Hydro Quebec as a Fellow of the Canadian Nuclear Society.

Dr. D. F. Torgerson

Dave Torgerson receives certificate from 1994-95 President Ed Price as he becomes Fellow of CNS

The second of the 1995 CNS Fellows is being recognized for establishment of, for technical contributions to, and for management of, Canadian research and development programs to support CANDU reactor safety and licensing, for leadership as AECL vice-president of Environmental Sciences and Waste Management, for many contributions in representing the Canadian nuclear industry of international bodies, for a more recent role in developing and promoting a vision of the CANDU reactor of the future and how to get there, and for many and varied active contributions to Canadian Nuclear Society activities. We welcome Dr. Dave Torgerson, AECL vice-president of Research and Product Development, as a Fellow of the Canadian Nuclear Society.

Professor R. E. Jervis

Bob Jervis receives certificate from 1994-95 President Ed Price as he becomes Fellow of CNS

The third of the 1995 CNS Fellows is being recognized for pioneering contributions to the development of neutron activation analysis in Canada, for continued development and industrial application of new techniques in this field of nuclear technology, for a key role in developing and teaching a comprehensive nuclear science and engineering curriculum for engineering students at both the undergraduate and post-graduate level, for a founding role and continued active support of the Canadian Nuclear Society and for many other contributions to the Canadian nuclear industry. He has received numerous other awards, including the W. B. Lewis of the CNS. We welcome Professor Bob Jervis, professor emeritus at the University of Toronto, as a Fellow of the Canadian Nuclear Society.

CNS Branch News

Manitoba

Igor, Show Our Guests to the Lab

by Morgan Brown

Someone on the executive of the Manitoba Branch of the CNS had the idea to hold a province-wide contest, the prize being a visit to AECL's Whiteshell Laboratories (WL) and the nearby Underground Research Laboratory (URL). Good idea. The CNS national executive gave us $500 towards transporting a Manitoba junior high class to visit WL and the URL. Now what do we do?

We started by getting a book listing all of Manitoba's schools and school divisions. To each school division we mailed a letter asking for Grade 8 or 9 classes to write and tell us why they wanted to visit WL and the URL. The replies were very good, but the 5-pager from École O'Kelly School at CFB Shilo was the clincher. They included a list of excellent questions for us to try to answer:

1. How many Canadians are employed in the nuclear power industry?
2. How is the nuclear industry regulated?
3. How safe will the disposal vaults be?
4. How many accident reports do you have filed on an average within a year from Canada alone?
5. Is plutonium sold from nuclear plants?
6. What are the chances of terrorists getting nuclear waste to make weapons?
7. How can nuclear radiation cause birth defects?
8. What are the different kinds of radiation?
9. Is irradiated food radioactive?
10. Are Canadians insured against nuclear power plant accidents?
11. What is a meltdown?
12. Why can't a nuclear power plant have an explosion?
13. Why is water a good temporary shield for radioactivity?

On June 16, 1995, after a three hour non-air-conditioned bus ride (in 35°C heat) from Shilo, 20 students and 3 staff arrived at the URL for an underground tour to a depth of 420 metres, led by AECL guides. The URL is AECL's main research facility to study the feasibility of storing used reactor fuel in an underground vault in the hard granite of the Canadian Shield.

The students then travelled to WL, about 20 km from the URL. Here, we (Judy Tamm, chair of the Manitoba Branch of the CNS, Tracy Sanderson, CNS executive member and coordinator of the visit, and I) greeted them, had the requisite group photo taken, and headed for lunch. I'd forgotten how much teenage boys eat! They kept asking about the film radiation badges they'd been given, and whether they'd beep, and where they should run if there was a radiation leak!

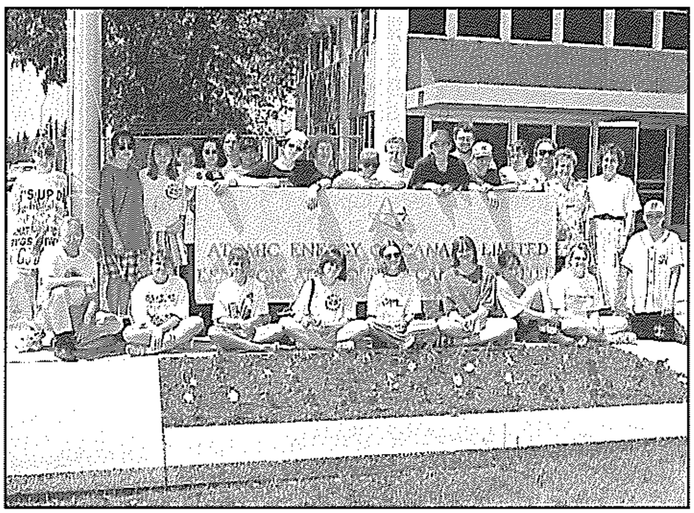
Following lunch, the visitors went to the public affairs theatre to try out geiger counters on samples of uranium ore, old glow-in-the-dark clocks, and the mantles from Coleman lanterns. After a short film describing some of the research work done at WL, the visitors were divided into two groups to tour the laboratories.

After the tour, the students were given a handout written by Dave Wren, vice-chair of the CNS Manitoba Branch, where he answered their list of questions. We've also sent the questions and answers to the other schools who entered our contest. Following Dave's presentation, our Shilo visitors headed back on their bus for the long trip home.

So, was it worth doing? Yes. We received an envelope filled with thank-you notes from the school, and our visitors evidently had a great time. The favourite part was going deep underground, as expressed by Joey: "After the tour of the Underground Research Laboratory I wanted to work there. I wanted to be a secretary, a tour guide, a scientist, a janitor or something. I was amazed by the depth of the centre." Holly also liked the URL the best: "At first we went 240 metres underground. It was neat how much the rocks and soil looked different that far underground."

It was well worth our effort to explain some of the mysteries of the nuclear world, and I think we encouraged the young people to consider careers in science and technology. There were several thank-you letters addressed to "Dear Doctor Scientist Guy" (a.k.a. Dave Wren). Jennifer wrote: "I would also like to thank you for answering our questions" and added hopefully: "P.S. Maybe some day I'll come back and make lots of money working for you."

Finally, we'd also like to thank the Corporate Relations staff at WL, especially tour guides Ann Duncan and Bella de Wit, without whom we couldn't have pulled it off.



Students from CFB Shilo visit Whiteshell Laboratories, June 16 1995

Sheridan Park

Prof. Bertram Brockhouse visits Sheridan Park

by Jeremy Whitlock

In June Professor Bertram Brockhouse was the special guest speaker at a seminar of the Sheridan Park Branch of the CNS, presenting an abridged version of his 1994 Nobel lecture, "Slow Neutron Spectroscopy and the Grand Atlas of the Physical World." This title invokes the metaphor of "geographical discovery" to summarize the role of scientists like Prof. Brockhouse in understanding the physical world. The synergism of Geography (theory) and Geology (observation), it was explained, represents a step-by-step building process which is the absolute heart of scientific learning. At Chalk River between 1950 and 1962, Prof. Brockhouse explored the "Geology" of our world at the solid-state level.

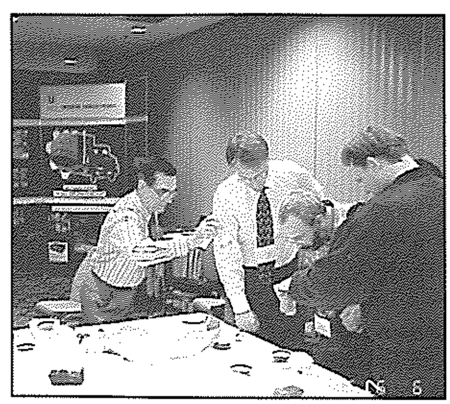
Prof. Brockhouse began by describing the background of neutron physics, starting with Chadwick's discovery of the neutron in 1932 and Bragg's description of neutron elastic scattering in 1936. By the 1950s the science was still young, generating about 50 papers a year, but it soon took off with the introduction of powerful research reactors like the NRX and NRU at Chalk River. Neutron beams from facilities like these fuelled an intense period of discovery in the fields of neutron optics, diffraction, and spectroscopy, and it was in the latter where Prof. Brockhouse made his award-winning contributions. His biggest legacy is the development of the "triple-axis spectrometer", and several powerful analytical methods associated with this device – all of which are still in wide use today. In the 1950s Brockhouse and his colleagues used these experiments to confirm the existence and explore the nature of "quasi-particles" such as phonons, magnons, and rotons.

A number of questions were fielded by Prof. Brockhouse at the end of his lecture. He was quite humble about his time at Chalk River, saying that he was happy enough to "get a job," and that he knew the work he and his team were doing was "interesting" at the time. On the overall worth of this work, Brockhouse feels that his most important contribution was to inspire "confidence in the use of the theory and language" of this nascent science. The actual work itself, he pointed out, has been repeated many times by others, and "probably better."

The factors that allowed such world-class neutron physics to be performed at Chalk River were placed into two categories: (1) the experimental facilities of the NRX and NRU reactors (while the former had the highest flux in the world, the latter was optimized for beam extraction), and (2) the solid and capable support from both the physics standpoint (Lewis *et al.*) and political standpoint (Mackenzie, Howe, Gray). One observer wondered if Prof. Brockhouse thought C.D. Howe could find the necessary money for the new IRF facility. After joking that Howe was talking about considerably smaller sums of money for research reactors in his day, Brockhouse emphatically stated that the IRF decision is inexorably linked to Canada's decision about whether to continue at the forefront of nuclear power development. If the answer to this is "yes" (as we all hope it is!) then the expense for an updated research facility is "minor" in comparison.

With this last point, Brockhouse returned to his opening theme of the cyclical and synergistic discovery process. He pointed out that nobody knows the future, and therefore it is necessary to maintain a basic research programme that is largely "curiosity-driven." Such a diffuse knowledge base allows an organization, from an entire country down to its labs like AECL, to be aware of what's "going on" around them and to capitalize on any development that shows promise. This being the case, the door to neutron physics, opened by early explorers like Brockhouse, should never be closed at AECL.

Aslam Lone, chairman of the CNS Education Committee, assists teachers with small cloud chambers at the educators' workshop during the CNA/CNS Annual Conference in Saskatoon in June, 1995.



CNS Annual General Meeting

About 50 members turned out for the 16th Annual General Meeting of the Canadian Nuclear Society which was held late Monday afternoon, 7 June 1995 in Saskatoon, at the end of the first day of the CNA/CNS Annual Conference.

Presided over by retiring president Ed Price, the meeting proceeded smoothly (if somewhat slowly) with reports from the president, treasurer and heads of the various committees and divisions. Even though there were no awkward questions as in some past years the meeting still ran well past the allotted hour.

As usual the slate of officers proposed by the nominating committee was accepted and with no further nominations those listed were declared elected by acclamation.

Following is the CNS Council for 1995-96:

President	Jerry Cuttler
1st vice-president	Hong Huynh
2nd vice-president	Ben Rouben
Treasurer	Ken Smith
Secretary	Aslam Lone
Members-at-large	Ernie Aikens Eric Jelinski Jeff Lafortune Emelie Lamothe Guy Le Clair Raymond Leung Jim Platten Surinder Singh Shayne Smith

Following are the addresses by the outgoing and incoming presidents and the treasurer's report along with the auditor's report and the annual financial statement for the calendar year 1994.

CNS Executive for 1995-96: back row, l. to r., Ed Price, past-president, Ben Rouben, 2nd vice-president, Ken Smith, treasurer; front row, l. to r., Aslam Lone, secretary, Jerry Cuttler, president, Hong Huynh, 1st vice-president.

Incoming president's address to AGM

Jerry Cuttler

Thank you all for coming and participating in our annual meeting. It's the major event in our calendar.

It's very appropriate to hold this meeting in Saskatchewan, which is playing a very important role in the development and utilization of nuclear science and technology in Canada. I'd like to praise the nuclear community here for helping to achieve the very positive attitude in Saskatchewan towards our technology. We need to do this in the rest of Canada.

It is a great honour and privilege for me to serve the Canadian Nuclear Society as your new president.

You all know that our Society is an amazing organization. I never cease to marvel at what we accomplish, time and again, by the entrepreneurial spirit and the volunteer efforts of our members. It seems that there's no limit to what we can achieve, if we infect enough people with our purpose and enthusiasm.

When I speak with prospective members about joining the CNS, I often hear the question, "what do I get for my 55 dollars?" We should answer by paraphrasing a former U.S. president, "Don't ask, what can the CNS do for you, but what can you do for the CNS?" Our objectives are worthy of the support of every individual in the nuclear industry.

In fostering the development and utilization of nuclear science in Canada,

- we have five technical divisions which organize an impressive calendar of technical events to give our members opportunities for personal development, broadening and exposure,
- we have twelve branches which hold many public meetings and support educational opportunities for students, with the very limited funds we provide,
- and, we act as a responsible voice in the public and political arena on nuclear-related issues.

It is clear that we are doing a good job in the first two areas. It's the **third** area that needs more attention – the public/political arena.

Why? Because nuclear science and technology will **not** survive in Canada without strong public support. We need only look south of the border to see what will happen here, and it has already started in Ontario. Most people are not aware of the benefits that nuclear technology already provides to all Canadians.

The public is afraid of trivial doses of nuclear radiation, thanks to the sensationalism of the news media and the unsubstantiated attacks by anti-nuclear pseudo-environmentalists who survive on intervenor handouts. Even our own health physicists label radiation as a carcinogen, regardless of dose, and they continue to endorse the linear model – a theory that scientists recognize as being at odds with reality – like the flat earth model, or the geocentric model of the universe. It appears in the teaching material in schools. The next generation is well on the way to rejecting nuclear technology, even in medicine.

I'm a firm believer in the notion that you can't fool all the people all the time. The truth will come out sooner or later. But if it comes out later, it will be too late for our technology to survive in Canada. Nuclear technology is too important for the health and prosperity of Canadians. The truth must come out sooner.

You will ask, "Why must *we* do it?" Isn't this the job of the CNA and AECL?

It is, but they have very limited resources. It will need the volunteer effort of many people who understand this advanced technology and have a stake in perpetuating it. Who can do it? Well, the CNS *is* capable of explaining our technology to the Canadian public in *simple* language, without resorting to mathematics. We can point out the tremendous benefits, the safety and how important it is for the public to support it. We must help our many members overcome their reluctance to speak out and challenge unscientific information that denigrates the development and utilization of nuclear technology.

The return on the sale of current nuclear products and services does not adequately fund the R&D needed for future products. Only with a high level of public support will there be continued funding for this purpose.

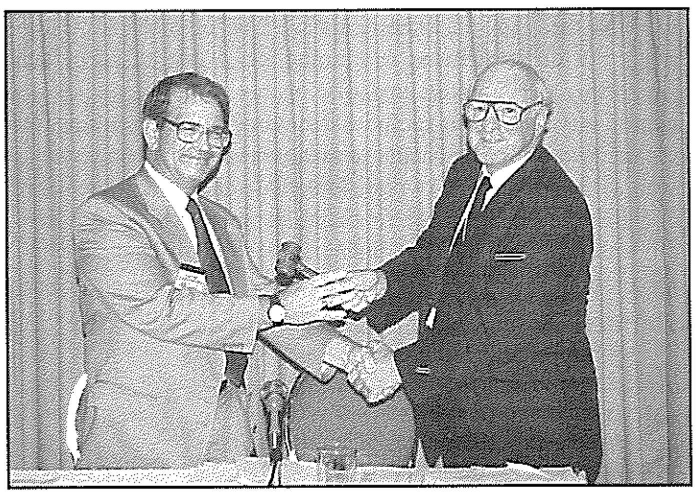
So this is where I will be trying to focus more CNS effort. We will continue to do the things we have been doing so well, *and* we will try to broaden our appeal by changing our image from a purely technical organization to one that is more publicly oriented – that speaks out often on issues of public concern. We will try to attract many of the tens of thousands of Canadians who are involved in nuclear technology and ask them to support the CNS.

So that, my colleagues, is where I want to lead you:

— a strong technical program
— strong, active branches, and
— plenty of action in the public/political area.

I look forward to your support.

Thank you.



Retiring president Ed Price hands over the ceremonial gavel to 1995-96 president Jerry Cuttler at the CNS Annual General Meeting, 7 June 1995, in Saskatoon.

President's Report

Ed Price

A significant aspect to the Canadian Nuclear Society's activities this past year has been the strengthening of ties to international organizations and other societies. As a technical society that serves an industry which recognizes the importance of the export market to its future, I believe that this has been an appropriate initiative. The Society has continued its support for the Pacific Nuclear Council and as many of you know, the Secretariat of the PNC is now located in the CNA/CNS offices in Toronto and our past president, Paul Fehrenbach, is the secretary to the PNC. The CNS submitted a proposal to the PNC and was awarded the 1998 Pacific Nuclear Basin Conference. This conference, with attendance from the emerging nuclear nations from around the Pacific Rim as well as nations with mature nuclear industries, will be an excellent opportunity to present Canadian Nuclear Technology. The conference will be held in Banff, Alberta.

We are continuing to support the activities of the International Nuclear Societies Council in its projects to prepare a 50 year vision for the nuclear industry, and to provide experts to facilitate the operation of the Convention on Nuclear Safety, currently being ratified by the world's nations. The Society has strengthened its ties to the American Nuclear Society, renewing our memorandum of understanding and supporting their efforts to establish cooperative research projects between university Nuclear Engineering Departments on both sides of the Pacific, under the banner of the Pacific Alliance.

Besides these activities the CNS is renewing agreements and initiating new ones with sister nuclear societies. In a less direct fashion, CNS retirees are planning to provide training modules in nuclear technology to nuclear engineering students and utility engineers, at Chulalongkorn University, Bangkok, at the end of the year. Members of the Society also participated in the successful first CNA/KAIF CANDU seminar which was held in Seoul in April of this year.

Each president of the Society tends to have interests influenced by his previous responsibilities on Council. My experience has been with the technical divisions and I see the successful operation of these divisions as the key to the well-being of the Society. The CNS receives 70% of its income from the surplus generated from the division activities. We endeavour to have each division hold a major conference every two years and a minor event in the alternate year. We are doing well in maintaining that average although the conferences in any one year sponsored by a division may be bunched together. Last year the Design and Materials Division sponsored two successful conferences, the Steam Generator Conference and the 3rd International Containment Conference as well as a Reactor Chemistry Course earlier in the year. The Nuclear Science and Engineering Division sponsored the Simulation Seminar in Pembroke and ran a fully subscribed and revamped Reactor Safety Course in Oshawa. This year the Simulation Seminar will be held in Hamilton, in November.

This year the Fuels Technology Division is sponsoring the CANDU Fuel Conference in Pembroke and the Operations Division, the Third CNS Maintenance Conference in Toronto in November. The CNS is also sponsoring a new course, The Effect of Reactor Physics on Reactor Design, again in November, and it promises to be well attended. The activities of the Waste Management and Environmental Affairs Division has been concentrated on preparations for the Waste Management Conference to be held in Winnipeg next year. We should remember too that this Annual Conference is our biggest technical conference with close to 100 presentations in the CNS sessions.

An event we share with the CNA in sponsoring each year, is the Student Conference. It is a pleasure to report that the event, which was held in Winnipeg in March, was again successful, as you have likely read in the *Bulletin*.

Our branch programs are very active and well received by our members. My experience from attending the Sheridan Park events is to see many of the events with standing room only, which is a tribute to the branch organizers and the speakers. One branch event in particular, that should be mentioned is the 50th Anniversary of ZEEP, which is being organized by the Chalk River Branch and the Education and Public Affairs Committee. This will be centred on the August 4-6 weekend in Deep River and we look forward to seeing many members present.

The Education and Public Affairs Committee under Aslam Lone has been very active introducing the basics of nuclear technology to teachers and organizing internet activities.

The finance committee under Ben Rouben has developed the financial statements into a clear and easily absorbed format with the help of the subcontract accountant. The Society's books were close to being in balance last year and hopefully we can manage the same this year with the smaller conference program.

The Honours and Awards Committee have introduced a new award this year that recognizes the team effort that is invariably necessary to get a concept into a practical application, and the award, named in honour of a founding member of the Society and its third president, John S. Hewitt, is to be given to the team of W. Morgan, D. McLean and M. Ohta for the development of the Dry Spent Fuel Storage technique. I believe this is a worthy initial award. We also congratulate their selection of M. Ross, D. Torgerson and R.E. Jervis as fellows of the Society.

Our membership remains at a good level but the magic 1,000 number is still eluding us. It is a little puzzling that we get great attendances at our conferences and branch events yet the membership remains at about half the level we could reasonably expect.

Finally, I want to thank Fred Boyd for his sterling efforts in producing that most visible of the Society's products, the *Bulletin*.

Overall, I believe it has been a successful year. It has required a lot of time and effort but it has been a rewarding experience. I want to thank the Council for its support, and wish the incoming President, Jerry Cuttler, the greatest success in the coming year.

Treasurer's Report

Ben Rouben

I am pleased to report to members that the Canadian Nuclear Society continues to enjoy a healthy financial position.

The budget for FY 1994 forecast a deficit of about $30,000, but thanks to a very good performance by all the Conferences and Courses we organized, the deficit was actually limited to about $2,500. As Treasurer, I would like to congratulate and thank all organizers for events which were not only technically, but also financially, very successful. This makes my job easier.

The assets of the Society stand at over $222,000. This includes our share in the joint Education Fund, which the CNA and the CNS initiated jointly. In view of the better-than-expected financial results in 1994, the CNS has in fact transferred another $5,000 into the Fund, bringing its share of the principal to $17,000.

It is important to note that membership fees account for only slightly more than 20% of total CNS income. About two-thirds of revenue in FY 1994 was from Conferences and Courses. Thus, a continued strong financial position of the Society depends on holding technical events which are of interest to members.

CNS Financial Statements for 1994

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

Auditors' Report

To the Members of the Canadian Nuclear Society

We have audited the balance sheet of the Canadian Nuclear Society as at December 31, 1994 and the statements of operations and surplus for the year then ended. These financial statements are the responsibility of the Society's Council. Our responsibility is to express an opinion on these financial statements based on our audit.

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

In our opinion, these financial statements present fairly, in all material respects, the financial position of the Society at December 31, 1994 and the results of its operations and changes in its financial position for the year then ended in accordance with generally accepted accouting principles.

Doane Raymond
Chartered Accountants
Toronto, ON
March 10, 1995

Deadline for Autumn Issue

Please forward all submissions to the editor
no later than **September 22, 1995**
so that production may begin on the
Autumn Issue of *CNS Bulletin*
in October

1994 Financial Statements

Canadian Nuclear Society Statement of Operations	Year Ended Dec. 31, 1994	Year Ended Dec. 31, 1993
Income		
Membership Fees	$ 36,327	$ 37,557
Publications	5,208	7,590
Interest	8,350	7,642
	49,885	52,789
Society projects – excess of income over expenditures		
Annual conference	28,387	21,300
Containment conference	30,408	—
Steam generator conference	22,178	—
Simulation Symposium (Int'l Simulation Conf in 1993)	13,804	29,379
Fusion Seminar – April ('93)	—	450
Reactor Safety Course – May	10,454	5,271
Rolled Joint Conference – Sept ('93)	—	13,000
1992 CANDU Maintenance Conference	—	(2,804)
1993 CANDU Fuel Conference	—	1,082
1993 Regional Overpower Trips Course	—	82
Chemistry Course	2,989	—
Recovery to prior year Education Fund Expenditures	—	3,500
	108,220	71,260
Total income	158,105	124,049
Expenses		
Net expenditures by Branches	16,316	11,654
Committees		
Membership	11,507	1,336
Program	4,408	1,352
Fusion	95	—
Awards	998	739
Education and Public Affairs	8,784	2,040
	25,792	5,467
Office Support	48,000	32,000
Office Services		
Audit fees	2,500	3,000
Canadian Nuclear Society Council expenses	1,631	4,536
Stationery and office supplies	5,586	2,619
Bank charges	457	399
Credit card charges	1,151	1,243
Computer programming	1,180	97
Telephone	1,428	1,843
Casual labour	615	—
Insurance	1,080	—
Postage	16,356	14,344
Copying facilities	2,400	2,400
Courier charges	517	155
	34,901	30,636
Canadian Nuclear Society *Bulletin*	20,698	18,906
Special Projects		
Student Conference	1,403	892
INC93 Proceedings publications	8,624	—
Officers' Seminar	4,185	—
International Nuclear Societies	700	—
	14,912	892
Total expenses	160,619	99,555
Excess of income over expenses	$ (2,514)	$ 24,494
Statement of Surplus		
Surplus, beginning of period	$ 208,282	$ 183,788
Excess of income over expenses	(2,514)	24,494
Surplus, end of period	$ 205,768	$ 208,282

Canadian Nuclear Society Balance Sheet December 31	1994	1993
Assets		
Current		
Cash		
Royal Bank	$ 365	$ 20,423
Nuclear Science and Engineering Division	—	7,168
Branch bank balances	13,296	15,454
Wood Gundy	74,101	68,417
Bank of Montreal	1,135	22
Receivables	33,548	47,445
GST receivable	1,725	—
Accrued interest	874	577
Prepaids	24	—
Marketable securities	91,318	69,924
Conference advances	6,500	5,000
	222,886	234,430
CNS share of Education Fund assets (Note 2)	17,000	12,000
	$ 239,886	$ 246,340
Liabilities		
Current		
Payables and accruals	$ 2,516	$ 6,905
GST payable	—	4,023
Membership fees received in advance	6,121	28
Due to Education fund	300	—
Due to Canadian Nuclear Association	8,181	15,192
	17,118	26,148
Surplus		
Accumulated Surplus	205,768	208,282
Education Fund (Note 2)	17,000	12,000
	222,768	220,282
	$ 239,886	$ 246,430

On behalf of the Canadian Nuclear Society Council
(signed) *E.G. Price* *B. Rouben*

Canadian Nuclear Society
Notes to the Financial Statements December 31, 1994

1. Summary of significant accounting policies
(a) Revenue recognition
Membership fees are included in income in the fiscal year to which they relate.
(b) Marketable securities
Marketable securities are carried at cost adjusted for amortization of premiums or discounts.
2. Education fund
From 1988 to 1991, annual contributions amounting to $3,000 from the Society and $7,000 from the Canadian Nuclear Association (CNA) were allocated from the income from the annual conference. In 1994, the Society made an additional contribution of $5,000. The principal remains the property of the CNA and the Society. The interest on these funds is available for educational purposes to local branches of the society.

The total fund is composed as follows:	1994	1993
Principal contributions		
Canadian Nuclear Association	$ 28,000	$ 28,000
Canadian Nuclear Society	17,000	12,000
	45,000	40,000
Annual interest available to Canadian Nuclear Society branches	9,387	12,015
	$ 54,387	$ 52,015

Nuclear Heritage Celebration

Over the week-end of August 4 to 6 a number of events are being held at Chalk river to celebrate the 50th anniversary of the start-up of ZEEP, Canada's first reactor, and of the beginning of Deep River, the residential town for the Chalk River Laboratories.

On Friday, August 4, there will be three special lectures, by Dr. Ralph Green, former AECL vice-president, Paul Scholfield, former president of GE Canada, and Dr. Dave Torgerson, AECL vice-president. They will, respectively, cover the history of AECL research, the role of GE Canada in Canada's nuclear development, and the future of nuclear technology in Canada.

That evening there will be a banquet at the Lions Club facility in Chalk River with guest speaker Alan Waltar, immediate past-president of the American Nuclear Society and manager of nuclear engineering at Westinghouse Hanford.

On Saturday, August 5, the Deep River 50th jubilee ceremonies will begin with the naming of Brockhouse Way after Nobel laureate Dr. Bertram Brockhouse. Over the rest of that day and the next there will be a number of exhibits and activities.

A further ceremony will be held September 5, the actual anniversary of the start-up of ZEEP in 1945 with a special seminar in Deep River at which former AECL Research president Dr. Terry Rummery will be the guest speaker.

For information contact Aslam Lone at CRL, telephone 613-584-8811 ext 4007.

Two-Phase Flow and Heat Transfer Course at McMaster

by Glenn Rossitter

A "Two-Phase Flow and Heat Transfer" course was offered for the first time at McMaster University in Hamilton, Ontario from May 8-12, 1995. This course was a new venture for McMaster and was modelled after similar courses offered at Stanford University and the University of California at Santa Barbara. There are however two key differences between the McMaster course and those offered at the other universities. First, the McMaster course emphasizes the fundamentals and applications specific to CANDU reactor thermalhydraulics. Secondly, the course fee of $963 (including GST) for Canadian Nuclear Society members ($1,177 for non-members) represents a substantial savings over the other comparative courses.

The course was so well received by industry that in addition to the 32 participants in the course, several more had to be turned away. While the majority of the participants were from Ontario Hydro and Atomic Energy of Canada Ltd., there were also representatives from Atlantic Nuclear Services, Hydro Quebec, Royal Military College of Canada and McMaster University.

The course covered both the fundamental aspects of two-phase flow and heat transfer, as well as providing applications specific to nuclear engineering. The course was intended to provide the theoretical basis of two-phase flow technology and bridge the gaps to nuclear reactor thermalhydraulics and safety analysis. It was particularly well suited for those either working in or interested in pursuing a career in the field of reactor thermalhydraulics.

A great deal of information was covered by the eleven highly qualified instructors over the duration of the five day course. Some of the many topics covered included: introduction to two-phase flow, pressure drop and void fraction, two-phase flow modelling, pool boiling, film boiling, critical heat flux, post dryout heat transfer, counter current flow instabilities, numerical methods, waterhammer and steam generators. Although there was a strong emphasis on applied mathematics and theory throughout most of the lectures, the real strength of the course was in the enthusiasm of the instructors, explanation of concepts and phenomena, and the overall quality of the presentations.

A detailed set of course notes were provided to help overcome the inherent difficulty of covering such a vast amount of material in such a short time frame. These course notes, complete with references, provide a valuable resource for further study on the many topics discussed.

In order to take a break from the theory and to get some exposure to the practical side of nuclear engineering, Dr. Shoukri arranged for a tour of the two megawatt McMaster nuclear research reactor. The 36 year old reactor is primarily used for course studies at both the graduate and undergraduate level, as well as some commercial applications. About 17 faculty members and another 24 researchers from other Canadian universities use the reactor for isotope production, neutron activation, neutron beam experiments and radiography. I must admit I was quite surprised to learn that the reactor utilizes 93% enriched uranium. Unfortunately, it was also at this time that we were informed that the reactor is to be shutdown and decommissioned as of next January due to a lack of funding.

Overall, this course was very informative and I would highly recommend it to others. It provided good insight into the complexities of modelling two-phase flow and heat transfer phenomena which are used in many thermalhydraulic codes throughout the nuclear industry. The course also reinforced the fact that the many mathematical correlations used in our computer codes represent our attempts at understanding and describing nature by means of simplifying and approximating equations. As safety analysts we must not only have a good appreciation of the methodology being used, but also be aware of the limitations inherent in modelling such complex real world phenomena.

Glenn Rossitter is a Nuclear Design Engineer at Ontario Hydro. He is currently working in the Containment Response unit of the Reactor Safety and Operational Analysis Department.

CNA/CNS Library

Because of the necessary reductions in staff at the CNA/CNS offices, the future of the library there is in question.

The Council of the CNS would like to hear from members regarding the use of, or interest in, the library, and of any suggestions for its future (such as operation by volunteers, donating its contents to another library, etc.)

Please contact any member of the CNS Council as listed in the box on the inside back cover.

Moral Panic: Biopolitics Rising, Second Edition (Revised), John Fekete, Robert Davies Publishing, Toronto/Montreal, January 1995.

Reviewed by Keith Weaver

There are books one would like to see reviewed by someone who is neither a woman nor a man. This is one of them.

Moral Panic is a book about failure to define things honestly, failure to collect and use information fairly, and, perhaps most of all, an urge to embrace spurious certainties and to defend this stance with whatever "evidence" may be at hand, all in order to avoid admitting that some uncertainties are ineluctable. It is likely that some people will regard *Moral Panic* as an unremitting book, unacceptable and scandalous in the case it presents. The author's case is directed at extreme feminism, "biofeminism" or "biopolitics", as expressed in his terms. His case says that unscrupulous methods have been used and are being used to generate fear. That fear is being induced in women. Fekete describes the biofeminist case in the following terms. There is a war against women, a war that is being waged by men. Virtually all women are targets and are at risk. By implication, all men are perpetrators. Men are demons. This is the state of moral panic that Fekete posits is being constructed. Once the epidemic nature of the problem (as "revealed" by the biofeminists) becomes evident, it is clear that draconian measures will be needed to protect women from the threat posed by men. These measures have already turned up in the form of legal and semi-legal provisions to be used for protecting women against any real or imagined threat from men. Fekete's objection does not arise because of the real threats. Far from it. It is the supposed omnipresent imagined threats (i.e. threats not actually known to exist) against which he makes his case.

John Fekete is Distinguished Research Professor of Cultural Studies and English Literature at Trent University. Most of his book *Moral Panic* deals with charges of sexual harassment and sexual abuse that have been made in university communities across the country. The consequences of these charges for the civil and human rights of the people involved is more than a little bit alarming. How such a situation could arise, how such accusations of abuse come to be levelled in the first place, is the question dissected in the first half of the book. They are allowed to arise, indeed are encouraged to arise, in response to the alarms of panic over a situation of supposed epidemic sexual abuse in Canada. The nights, even the days, are thick with rapists, abusers, tormenters. No woman is safe. All men are suspect. The only response that can possibly work is an extreme one. Just how extreme this response is and how much more extreme it could become, is described.

In everyday life, two consequences of this activity are the numerous "zero tolerance" agendas and the pervasive political rectitude that suffuses much of our business and social dealings. Political correctness, in particular, has been made the butt of numerous jokes, and has become the source of an odd type of world-weary humour. To laugh about it, however, is a mistake, says Fekete. Political correctness is in part a symptom of moral panic, and as such it is not at all a laughing matter but deadly serious. In universities, the response to the sexual panic is perhaps at its most vicious. Professors, both men and women, are "disciplined" or harassed, both by students and by their own institutions, for supposed sexual abuse or for making statements that some regard as inflammatory. These disciplinary actions are brought by the universities' equity or sexual harassment offices, sometimes by third parties, and in some cases even over the objections of the people who are supposed to have suffered the abuse. Sometimes the accused are kept in the dark as to the charges or as to the identity of their accuser(s). They can be tried, convicted as charged, and "punished" by university committees, without a formal opportunity to defend themselves. Equity and sexual harassment officers wield tremendous power against any such accused, and in conjunction with university officials have damaged or ended careers without any due process being followed, and without the possibility of appeal. The list of people presented by Fekete is distressing: Professor Jeanne Cannizzo, University of Toronto, Professor Richard Devlin, York University, Professor Richard Hummell, University of Toronto, Professor Phillippe Rushton, University of Western Ontario, Professor Larry Belbeck, McMaster University, Professor Jacques Collin, University of Manitoba, Profesor Lucinda Vandervort, University of Saskatchewan, Professor Marjorie Ratcliffe, University of Western Ontario, Professor Heinz Klatt, King's College, University of Western Ontario, Professor Irwin Silverman, York University, Professor Reg Whitaker, York University, Professor Paul Lamy, University of Ottawa, Professor Vedenand, University of Manitoba, Professor Matin Yaqzan, University of New Brunswick, Professor Alan Surovell, Dalhousie University, Professor Ken Westhues, University of Waterloo, and Professor Warren Magnusson, University of Victoria. As Fekete presents their cases, all these people have had their human rights, or their right to freedom of speech violated. The violations have arisen because of excessive zeal, a stacked deck, weak or compliant administrators, and the whole affair being driven and fed by moral panic.

Fekete's point of departure in writing *Moral Panic* is of interest.

"My voice, in the past, has been upbeat, devoted to the utopian prospects made possible by the radical will. I have come to believe that the radical (utopian) will and the radical (utopian) will-to-openness set up between them the indeterminate energies that can keep us creative in the actual world and tolerant of its differences. This book, I hope, tells a very strong story. In fact, it tells at lot of stories. I should emphasize that the stories are Canadian, although their implications are in many ways international. Most discussions of the issues I deal with draw overwhelmingly on American examples. This is hardly necessary. It is a dubious pleasure to disclose that in the domain of biopolitics, and especially biopolitical policy, Canada yields second place to none, and these stories can serve as cautionary tales for others. The stories related here, and the story telling, may sound critical. They may even be critical of the radical will. But we have to know that, left to their own devices, utopian practices can go over the top and diminish the life they hope to improve. The impact of the utopian will can be as negative as its absence.

"It is a deep paradox of our scope for change that uncertainty must be taken into account. If we cannot be sure of the future, then the present must not be treated with contempt. My intention remains upbeat, and also decidedly open-ended. I resist the degradation of the past, in the name of the present, and in the name of the

unfulfilled hopes of the past. I resist the degradation of the present, in the name of the future, and in the name also of the complex density of our being. I resist the effort to change the historical world in rhetorical time. I defend the most precious achievements of human rights struggles in Western modernity: the fundamental freedoms (including freedom of expression, attitude, and opinion), and due process. I believe these are primary substances and enabling frameworks of equality as well."

There can surely be no doubt that there is violence against women (and others) in our society. The questions are how much, who does it, why and how can it be stopped. Fekete argues that the biofeminists are making it virtually impossible to answer these questions. They are doing this by massively over-exaggerating the problem. In the wake of this over-exaggeration, policy is formed in a state of panic: moral and sexual panic. The result is a vast scattergun aproach (if all men are perpetrators, then it scarcely matters who you hit), and the real problem is lost in all the smoke and shouting. Fekete targets one particularly influential study to illustrate the nature, the extent and the callousness with which this over-exaggeration is carried out. The study is "Changing the Landscape", the Final Report of the Canadian Panel on Violence Against Women (1993). This report is worth study, according to Fekete, not because of any intrinsic value (he claims it is "not worth touching, intellectually speaking"), but because it is "the encyclopaedic version of everything that is wrong with contemporary biofeminism" and because "it spells out in astonishing detail the biopolitical vision of a properly administered society".

Fekete brings enormous fire power to bear against this and other studies. Possibly too much. Anyone treated to this kind of criticism in a master's or doctoral programme, would probably step outside and shoot themselves forthwith. Unhappily, if Fekete is correct, the criticism he directs at the Canadian Panel's work is justified. To give a flavour of both target and critic, I will try to summarise the author's discussion of two dramatic and astonishing statistics that the Canadian Panel uses in its report. The report states, "When all kinds of sexual violation and intrusion are considered, 98% of women reported that they personally have experienced some form of sexual violation". The Panel also reported that "women with disabilities are more vulnerable to violence. According to one source, approximately 83 percent of women with a disability will be sexually assaulted during their lifetime." These numbers are extraordinary. (When the Panel's report appeared, the press expressed incredulity at some of its numbers, particularly these.) Even more extraordinary, however, is the trail that Fekete had not only to follow, but first of all to unearth, in order to determine the origin of these statistics.

First, the 98% figure. Fekete documents, over approximately 10 pages, the searching done by him and his research assistants to get to the bottom of this number. A year after the Canadian Panel's report was out, the Panel was long since disbanded, and no information could be obtained from those who had actually prepared the report. The figure was referenced to work done by the Women's Safety Project (WSP). The authors of the relevant WSP study were contacted, but it transpired that their report had not yet been published. Many telephone calls to authors and sponsors only made matters less clear. Two conflicting drafts were eventually unearthed. In the end, Fekete found that it was impossible to derive the actual 98% number from the WSP drafts, so confused and contradictory were the data and interpretations. What he was able to determine, however, was that the WSP interpreted "sexual violation" to mean anything from rape at knife point to nudges and glances. Fekete characterises the WSP work as inconclusive, inconsistent, often chaotic, scientifically worthless and the epitome of sloppy amateur advocacy. And yet this is a centrepiece statistic of the Canadian Panel's report.

Second, the 83% figure for disabled women. The path that had to be followed in tracking down the provenance of this statistic can only be called bizarre. The Canadian Panel cites as its source for the 83% number, a study by Liz Stimpson and Margaret Best, "Courage Above All". This report was nowhere to be found. The sponsoring body, the Disabled Women's Network (DAWN) Toronto, could not provide a copy and the report was out of print. Fekete's research assistant eventually located a copy herself in the DAWN library. The report cited another source for the number, a lecture at Northern College in Timmins. It turned out that Stimpson used the figure, knowing that the author of the Timmins paper could not remember where it came from. After further probing, Fekete was able to determine that the 83% figure came from a 1986 lecture delivered in Omaha, and continued delving eventually produced a copy of the paper which is the original source of the 83% number. The situation, as it was finally revealed, is staggering.

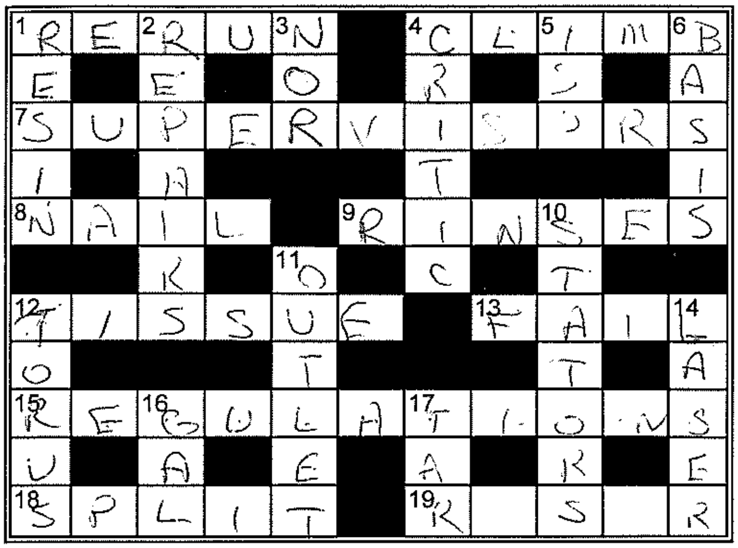
The 83% statistic comes from a study done by the executive director of the Indian Wells Valley Association for Retarded Citizens, in Ridgecrest, California. Stripped to its grim reality, the 83% number is based on interviews of 28 retarded women. What has happened, then, is that a study of past experiences of 28 women, who are completely unrepresentative of the relevant Canadian female population, has been generalised by the Canadian Panel to a statement that 83% of disabled Canadian women *will be* sexually assaulted.

It is on evidence such as this that Fekete rests his argument about moral panic. The panic, the epidemic, has led to the witch hunts at universities, and to a number of criminal cases in which men have been accused of sexual abuse, in some cases imprisoned for months, only to have it revealed that the cases rested on fabrications. Figures from Statistics Canada indicate that 14% of sexual assault complaints have been determined by the police not to have happened nor been attempted. For the more specific case of rape, U.S. sources indicate that numbers of 27%, 40% and 60% (three different groups of cases) of alleged rapes never happened. If Fekete is correct, and such cases result from fear, panic and confusion, we are all in trouble. Nobody will benefit from any of this, not women and not men. In the end, the losers will be those women who really are abused because their stories will be lost and discredited in a sea of propaganda.

This is grim stuff. Or is it really? How should one characterise the book, actually? Is it alarmist? Is it, in fact, misogynist? Is there really so much hatred, misunderstanding, fear, panic and misandry out there? Has he somehow got it all wrong? By stating the case so strongly, is he running the risk of generating a backlash against equity and other programmes, more importantly against women themselves? (If the situation is actually as he depicts it, then I fear that such a backlash is probably inevitable.) These are all things to be thought about by men who have wives, daughters, mothers and sisters, by women who have husbands, sons, fathers and brothers, and by all who have lovers, friends and colleagues. Fekete states his case strongly, perhaps too strongly for some readers. In the end, the real value of the book may be the warning it raises about fundamental freedoms, how we take them for granted, how precious and fragile they may actually be, and what blackness we would all fall into if we ever let go of them. *(cont'd on page 43)*

The Cross Section: No. 3

Easier



Solutions appear on the inside back cover above the CNS Council Box

Clues

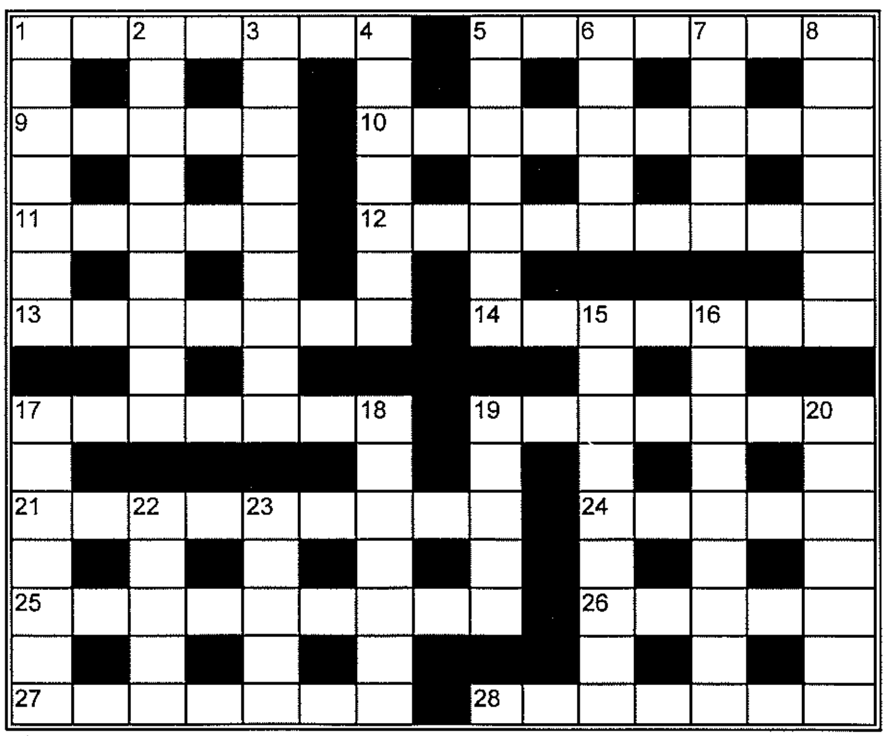
Across

1 Movie played again, about the footrace (5)
4 Ascend tree (5)
7 Heads of shift make great sunshades (11)
8 Small version of spike (4)
9 Sirens produce multiple laboratory operation (6)
12 Paper hankie is not quite at issue (6)
13 Not to succeed (4)
15 Rules (11)
18 What uranium atoms do (5)
19 Modify sire's vertical pipe (5)

Down

1 Reformed siren makes exchange (5)
2 Latin thing swallows couple leading to overhaul (7)
3 Complements neither, backward Ron (3)
4 One who finds fault (6)
5 Prefix is also standards body (abbr) (3)
6 Underlying design rationale (5)
9 Fixed coils of generator (7)
10 A reactor header (6)
11 Tokamak element involves convoluted tours (5)
15 Coherent light device, comparatively (5)
15 She's in a drum, with 44 others (abbr) (3)
16 A sticky black sailor (3)

Harder



Clues

Across

1 In the meantime, I'm inert but confused (7)
5 Whiteprints revised (7)
9 Thermalhydraulic phenomenon describes snowbank (5)
10 French mathematician, similar to soft cheese (9)
11 Cold Italian (5)
12 Future friend in arms moves sideways (9)
13 Daniel expires as a fancy boy (7)
14 Valves to control air flow (7)
17 Fisherman reformulates problem? (7)
21 Temporary reactor overdose (6,3)
24 Possibly operators for information search (2,3)
25 Duct exits from boiler (9)
26 Here, but where exactly, mon vieux? (2,3)
27 Choose index variable, patriotically? (3,4)
28 Something to be resolved (7)

Down

1 Said of births and currents (7)
2 Crystalline form, reminiscent of three hospitals (9)
3 Reconstructs after completion (9)
5 Functionally associated (7)
6 Mired? Two atoms joined (5)
7 An agreement is an agreement (1,4)
8 Used for hearing? Clearly not (3,4)
15 Silk road explorer (5,4)
16 Vital (9)
17 Sand pile becomes stable? Could also be 17 across (7)
18 Sting engulfs Boolean operator for warehousing (7)
20 Metal following helium (7)
22 Noble but vaporous (5)
23 Spelled "mole" as well (2,3)

CALENDAR

1995

August 4-6

Celebration of Canada's Nuclear Heritage
Chalk River, ON
contact: Aslam Lone
AECL-CRL
Tel.: 613-584-8811 xt 4007

September 7-8

Status and Prospects of Fusion Power Development
Toronto, ON
contact: Shayne Smith
Wardrop Engineering,
Tel.: 905-673-3788
Fax: 905-673-8007

September 10-15

NURETH-7 – International Meeting on Nuclear Reactor Thermal-hydraulics
Saratoga, NY
contact: Dr. Michael Z. Podowski
Rensselaer University,
Troy, NY
Tel.: 518-276-6403
Fax: 518-276-4832

September 17-20

International Topical Conference on the Safety of Operating Reactors
Seattle, WA
contact: Dr. D.J. Senor
ANS, Richland, WA
Tel.: 509-376-5610

September 25-29

GLOBAL '95, on the Back End of the Nuclear Fuel Cycle
Versailles, France
contact: Dr. J.Y. Barre
CEA, Saclay Gif-Sur-Yvette, France
Fax: (33.1). 69.08.90.93

October 1-4

Fourth International Conference on CANDU Fuel
Pembroke, ON
contact: Mark Floyd
Chalk River Laboratories
Tel.: 613-584-3311 xt 3899

October 15-17

1995 Simulation Symposium
Hamilton, ON
contact: Dr. Guy Marleau
Tel.: 514-340-4204

October 29 - November 2

ANS Winter Meeting
San Francisco, CA
contact: ANS office,
Chicago, IL
Tel.: 708-579-8258

November 19-21

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

1996

February ??

CNA/CNS Winter Seminar
Ottawa, ON
contact: Sylvie Caron
CNA/CNS office
Toronto, ON
Tel.: 416-977-6152 xt 18
Fax: 416-979-8356

February ??

Plutonium Disposition with CANDU
Ottawa, ON
contact: John Luxat
Ontario Hydro
Toronto, ON
Tel.: 416-592-4067

February ??

CNA/CNS Student Conference
Ottawa, ON
contact: Sylvie Caron
CNA/CNS office
Toronto, ON
Tel.: 416-977-6152 xt 18
Fax: 416-979-8356

March 25-29

Nuclear Industry Exhibition
Beijing, China
contact: Xu Honggui
Chinese Nuclear Society
Beijing, China
Fax: 86-1-852-7188

April ??

Conference on CANDU Fuel Handling
location TBA
contact: Ron Mansfield
Mississauga, ON
Tel.: 905-823-2624

May 6-8

ANS Topical Meeting on Nuclear Plant I and C and Human-Machine Interface
University Park, PA
contact: Dr. R.M. Edwards
Penn State University
Tel.: 814-865-0037
Fax: 814-865-8499

June 9-12

CNA/CNS Annual Conference
New Brunswick
contact: Sylvie Caron
CNA/CNS office
Toronto, ON
Tel.: 416-977-6152 xt 18
Fax: 416-979-8356

July 21-26

ASME Pressure Vessel Conference
Montreal, PQ
contact: Dr. R.C. Gwaltney
Oak Ridge National Lab.
Oak Ridge, TN
Fax: 615-574-0740

August 18-24

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

September 16-19

Deep Geologic Disposal of Radioactive Waste
Winnipeg, MB
contact: M.M. Ohta
AECL Research,
WL Pinawa, Manitoba
Tel.: 204-345-8625 xt 201
Fax: 204-345-8868

September ??

5th International Conference on Numerical Methods in Nuclear Engineering
Montréal, Québec
contact: Hong Huynh
Tel.: 514-392-5614

September 29-October 2

Canadian Society for Chemical Engineering Annual Conference
Kingston, ON
contact: Dr. H.W. Bonin
RMC
Kingston, ON
Tel.: 613-541-6613

Book Reviews *(cont'd from page 40)*

So. What's the answer? It is perhaps too much to expect a clear direction to emerge, much less for it to be provided by one person. Fekete offers little, other than a hopeful, upbeat, but very general conclusion to his book.

"We create the culture inside which we live. A panic culture of group antagonisms is worse than one dedicated to individually based liberties, equalities and communities. It is better to seek strength than protection, equality than equity, personal responsibility than scapegoating, and complexity than simplicity. We have to cope with each other as real people, and we cannot rely on regulations to govern all our interactions, much less what we say to each other. We approach each other on the basis of our differences and have to negotiate shared transactions, not take offence at differences. Adults have to be encouraged and expected to act like adults, and acquaintances and strangers have to be allowed to enact themselves in public space, rather than be made to conform to the desires of designated groups for pacification of their surroundings. Women have to be invited and enabled to ally with men in public political life, for or against other women, and/or men. Individuals have to be able to escape from groups. Intellectuals have to be able and willing to be rude to movements."

Black Holes and Time Warps: Einstein's Outrageous Legacy, Kip S. Thorne, Norton, New York, 1994.

Reviewed by Keith Weaver

In the early 1970s, I worked in London. It would be satisfying to say that Roger Penrose dragged me off regularly to a pub buzzing with academics, to consult me on his latest mathematical researches. Or that Martin Rees would seek out my interpretation of his radio-astronomy images. Alas, the reality is much more prosaic. I worked on the third floor of an architecturally disadvantaged structure which, had it been human, would have been rushed to the nearest hospital and placed under close observation. In this office I toiled producing or editing abstracts from patents. To describe this work as "gripping" would be a more than trivial over-estimate of the intellectual intensity of my days there. Naturally, there were compensations: being young, with no debts, no responsibilities, footloose in London, and cultivating a new found taste for good beer. Indeed, far more exciting than my work was the daily challenge of avoiding death beneath the wheels of the Number 38 bus. Or bashing through the scrum that always formed around the curried chicken in the local pub at lunchtime. Or finding the typo of the week: "urarium", "henyene" and "antacid" (the last-mentioned being a direct but not quite faithful translation of "Ameisensaure").

Another compensation turned up each Wednesday. Wednesdays were special. Every Wednesday the *New Scientist* was published, and provided reading on the tube from Victoria to Holborn. During this time, there was at least one story a week in the *New Scientist* on black holes. I read them all. These thoughts were at the back of my mind when I picked up Kip Thorne's book.

Kip Thorne is the Feynman Professor of Theoretical Physics at Caltech. His excellent book brought me up to date after twenty years of inattention to black holes. In 619 pages he covers their history and their physics with great lucidity and readability, and an engaging humility. The story includes well-cast accounts of the past greats (Einstein, Eddington, Oppenheimer, Lifshitz, Landau, Zel'dovich and Chandrasekhar), as well as the present greats (Hawking, Penrose, Sciama, Wheeler, Rees and Israel). But perhaps best of all is the personal touch that Thorne puts into the very wide range of topics he covers. And the range of topics is wide, from spacetime, to curvature, neutron stars, quasars, gravitational waves, white dwarfs, Weber bars, gravitational interferometry, a full history of black holes, quantum foam, wormholes and time machines. Most importantly, the story unfolds in a natural, chronological way, told by someone who was there. In the telling, it is easy on the reader: one can readily understand, in fact to enjoy, Thorne's account without having to rent an atticfull of astrophysics texts. Furthermore, the characters are real people set in their own real time.

There are a few minor quibbles, the most significant being geographical. American authors (or perhaps their publishers) seem convinced that the short everyday names of major world cities can be used safely only when addressing the wildly over-educated, and that the full names (Parisfrance, Berlingermany, and Losangelescalifornia) are necessary to drive the meaning home for the general reading public. Admittedly, a minor quibble.

In all, it is an thoroughly enjoyable book, and it carried me back to another time and place, and to other things that I have always naturally associated with black holes: the crush of commuters in Victoria station, the scotch egg vendors in Southampton Row, the fat publican at The Lamb in Lamb's Conduit Street, and the cool, shaded benches in Lincoln's Inn Fields. I can picture myself there now...

"Ah, Roger. Do have a seat. Now, tell me seriously. Surely you don't actually expect me to believe these statements in your paper on accretion disk mechanics..."

by George Bauer

A journalist named Todd Wilson was on his way home from work about three weeks ago. He stopped into Mr. Grocer to pick up a few things and he noticed it. At the time, he paid little attention, and it was only some hours later that the matter resurfaced in his mind. Not being able to make sense of it, he telephoned me after finding an old business card I had given him. I had no real idea what it all meant and I told him so. But a bit of digging soon revealed what was going on.

What Wilson had seen was a small group of rather vague men, short back and sides, pocket protectors, baggy trousers, who were shuffling confusedly around the supermarket. As a group. Without wives. This was odd enough, but it was what they were carrying and what they were buying that had really piqued Wilson's interest.

About 10-15 years ago, supermarkets everywhere were plagued with the dreaded decimal-heads. Also known as the "Hewlett Packers", these chaps became addicted to the application of all sorts of advanced mathematics to the "shopping problem". They clogged checkout lanes. They terrorised cash desk operators. One could find them, having assembled data from all over town, busy regressing to the mean on samples of carrot prices. There were rumours that some of them applied tomography to watermelons in attempts to determine the size and number of seeds they contained. I personally investigated a case in which one of the Hewlett Packers landed up in hospital as a result of his destructive testing of turnips. The well known case of the nerd who applied too much ultrasound energy to a musk melon needs no repetition. The Hewlett Packers could be easily spotted in almost any supermarket. Massive calculators hung from their belts and had all the menace of Buntline Specials. They used fearful intimidation tactics, their stern gaze from beneath beetle brows challenging checkout clerks to come up with any answer but the one leering out from their LED displays.

This phenomenon died out as quickly as it appeared, and as inexplicably. Todd thought that he may have been seeing a reappearance. He was wrong.

After a couple of days checking, several things became clear to me. The nerds were indeed nuclear engineers. They were not evaluating supermarket prices, nor checking on the accuracy of checkout clerks. They were clearly carrying out a scientific experiment.

I watched a group of them on June 24 at the Mr. Grocer store on Bayview Avenue. Five of them moved through the store with two shopping carts, three calculators and two laptops. One of the shopping carts contained 15 pounds of onions, an assortment of spices and 25 litres of mineral water. The second cart groaned under the weight of 40 pounds of tomatoes. Two clipboards were produced at intervals and curves and tables were consulted. Calipers and strain gauges were applied to a sample of the tomatoes. A modified Charpy notch test was being used on several of the onions.

They soon finished and bundled all their goodies (and themselves) into two cars. I followed them to an address in a not so fashionable part of Leaside. The five of them lugged their produce inside. I approached the back of the house by an access pathway from the neighbouring street. Nothing was visible through any of the windows which were all clouded with steam. I did the only thing possible: I knocked on the front door. A shudder went through me when it was opened.

I faced a muscular individual whose arms and shirt front were covered in blood.

"Can I help you?", he asked.

"Can I drive you to the hospital?", I asked.

His brow furrowed, but then he smiled and said that it was okay.

This didn't really clarify things a whole lot. I asked if I could come in. He asked why. I said because I was George Bauer and I was interested in what five nuclear engineers were doing with 40 pounds of tomatoes. He recognised the name and after a short delay I was hesitantly asked to come in. A pungent smell pervaded the whole house. The kitchen was where the action was centred, and it could have been the subject of a Hieronymous Bosch painting. Clouds of steam filled a room in which water dripped from every surface. A clock above the sink had stopped, obviously not environmentally qualified. Three huge vats bubbled evilly on an enormous gas range. A smaller cauldron had tipped over leaving a broad streak of red that crossed the floor and disappeared under a table. In one corner cringed a poodle, originally white but now looking like it suffered from terminal red measles, and threatening to infarct any second.

The story was not long in emerging. They were making ketchup.

One might have supposed that here was some part-time entrepreneurship in action. But no. This was one of those interesting ideas that ran away with itself.

"You can't come to any appreciation of the inherent quality of a maintenance report, or a safety assessment report", the muscular one reported. "We decided that we had to try making something that we could evaluate in a more direct way. How can you make any statements about the quality of electricity?"

Questions on what was wrong with the existing measures of achievement were met with blank shakes of the head. They had to experience what they called the act of creation for themselves.

I asked the obvious question: Why ketchup?

After a bit of shrugging, several of them inclined their heads toward the chubby fellow stirring a huge vat: "It was Hinkley's suggestion. He likes ketchup."

Eventually they gave me a bottle. In the end, they were able to produce only twenty bottles before they burned out the motor on their only blender. A number of the neighbours were quite alarmed to see three men pouring gallons of blood down the storm drain at 1 a.m. No divorces occurred that I know of. The value of Heinz stock remained stable throughout.

The ketchup was quite good; a little heavy on the cloves. I hear that the poodle ran away from home.

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Easier

R	E	R	U	N		C	L	I	M	B
E		E		O		R		S		A
S	U	P	E	R	V	I	S	O	R	S
I		A				T				I
N	A	I	L		R	I	N	S	E	S
		R		O		C		T		
T	I	S	S	U	E		F	A	I	L
O				T				T		A
R	E	G	U	L	A	T	I	O	N	S
U		A		E		A		R		E
S	P	L	I	T		R	I	S	E	R

Harder

I	N	T	E	R	I	M		R	E	D	R	A	W	N
N		R		E		O		E		I		D		O
D	R	I	F	T		D	A	L	E	M	B	E	R	T
U		C		R		U		A		E		A		E
C	A	L	D	O		L	A	T	E	R	A	L	L	Y
E		I		F		E		E						E
D	A	N	D	I	E	S		D	A	M	P	E	R	S
		I		T						A		S		
R	E	C	A	S	T	S		A	E	R	O	S	O	L
E						T		N		C		E		I
P	O	I	S	O	N	O	U	T		O	R	N	O	T
O		N		R		R		W		P		T		H
S	T	E	A	M	L	I	N	E		O	U	I	C	I
E		R		O		N		R		L		A		U
S	E	T	F	L	A	G		P	R	O	B	L	E	M

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