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Editorial

Some Cheering News

At a time when, at home and abroad, not only are many people pronouncing the nuclear industry dead but also composing its epitaph and excavating the grave, there is news from AECL CANDU Operations that suggests in Canada at least the industry is not only alive, but kicking creatively.

The CANDU 300 concept has been under investigation for the last three years, at varying levels of intensity, but now it appears to be fairly well nailed down, and it is clear that this reactor could be the first in the line of reactor systems described by Dan Meneley in a previous *Bulletin* as the "CANDU better." Time is money, and nowhere is this better illustrated than in nuclear plant capital costs. It is extended construction schedules (with the concomitant cost escalation) more than anything else that have hammered nuclear economics south of the border. CANDU 300 tackles this problem head-on with a collection of developments which, according to a senior AECL official, could result in a total construction time for a CANDU 300 station of 38 months.

Dramatic while this is, the reduced construction time is only part of the story. While conventional "economies of scale" principles argue for a small number of large generating units rather than a large number of smaller units, a risk-averse customer would rather fall into a 300 megawatt hole than a 600 megawatt one. The smaller size reactor provides a first-time CANDU user a gentle, and minimum (economic) risk entry path into a nuclear generating program.

The CANDU 300 project seems to represent an imaginative and courageous step forward in nuclear power plant design and offers the prospect of demonstrating principles and techniques which could be profitably applied to the construction of larger CANDU units. It would be unrealistically optimistic to suggest that the sales prospects for any nuclear power system anywhere offshore are particularly rosy at the present time, but it would be foolishly pessimistic to abandon attempts to gain those sales, and CANDU 300 looks like an especially promising attempt. More significantly, perhaps, CANDU 300 signals a major step in the long-term engineering development of the CANDU system — development we cannot afford to do without.

Contents

Perspective

The Fusion Blanket Program at Chalk River

By I.J. Hastings, Manager, Fusion Blanket Program, Atomic Energy of Canada Ltd. Chalk River Nuclear Laboratories.

Atomic Energy of Canada Limited (AECL) is in the process of assuming the lead role in Canada's fusion effort, as a result of recent federal government decisions calling for the staged transfer of fusion responsibility from the National Research Council to AECL. Transfer of the program, which is funded under the Energy, Mines and Resources' Panel on Energy R&D, should be completed by April 1987. Major components involved are the Tokamak de Varennes and the Canadian Fusion Fuels Technology Project (CFFTP). AECL has had a fusion program at Chalk River Nuclear Laboratories since 1983, co-founded by CFFTP and concentrating on the fusion blanket, tritium recovery and storage, monitoring and biological effects. The Fusion Blanket Program utilizes CRNL experience in instrumented irradiation testing, ceramics, tritium technology, materials testing, and compound chemistry.

Lithium ceramics are favoured by many to make up the blanket that will surround the plasma in an operating fusion reactor. The blanket material will be irradiated externally by fusion neutrons from the D-T reaction and internally by fast ^{3}He and ^{3}H (tritium) ions, formed in ^{6}Li + n and ^{7}Li + n capture reactions. Heat generated in the blanket will be removed for conventional electricity production; tritium will be swept from the blanket by a carrier gas, reprocessed, and re-introduced into the plasma as fuel. It is impractical to test all possible candidate materials for fusion reactors by irradiating with fusion-energy neutrons because of the cost in building high flux, 14 MeV neutron facilities. An alternative approach is to examine fundamental and engineering properties of candidate materials by irradiating with neutrons in fission reactors, or with particle beams in accelerators. These techniques allow scoping tests on blanket materials, and form the basis of

the Fusion Blanket Program at Chalk River.

The major irradiation testing facility at CRNL is the NRU research reactor. NRU has the capability for two types of irradiation tests to evaluate solid breeder ceramics. The unvented capsule tests, designated CREATE (**C**halk **R**iver **E**xperiment to **A**ssess **T**ritium **E**mission), are those that do not have tritium release instrumentation (thermocouples and flux detectors can be included). Tritium release information is obtained after the irradiation is complete, and the capsule is removed from the reactor. These tests can measure the interaction between the ceramic and the cladding material; also pellet swelling, cracking, and grain size and pore size changes can be observed, as well as the amount of tritium remaining in the ceramic. Information is obtained on the form of tritium released, as a function of capsule material and sweep gas. Maximum sample size is 2 cm diameter and 15 cm long, but typically, samples weighing 50-100 mg are cut from sintered pellets of the ceramic for irradiation. Each sample is vacuum-annealed in a quartz tube, and sealed in the tube for irradiation without further exposure to air, then irradiated for 48 h at an estimated temperature of less than 370 K. The maximum flux is $4x10^{18} n \cdot m^2 \cdot s^{-1}$ (thermal) and $7x10^{17} n^2 \cdot m^2 \cdot s^{-1}$ (>1 Me V). The free tritium recovered at room temperature is measured, as well as the isothermal tritium release at the post-irradiation test temperature; both tritiated water and reduced tritium are determined. The tritiated water may include T_2O and HTO, and the reduced tritium T_2 and HT. Both He and He-1% H_2 are used as sweep gases at a flow of 0.5 L/min, with oxygen and moisture contents of the purified gas less than 1 μL/L and extraction vessels constructed from quartz, stainless steel, Inconel-600 and nickel are available. All post-irradiated tests are performed at 873 K for 4 h; tritium remaining in the ceramic after annealing is determined by liquid scintillation counting. Four tests on $LiAlO_2$ and Li_2O in the CREATE series have confirmed that, under reducing conditions (He-H_2 sweep), most of the tritium (>70%) is released as HT or T_2; the balance as HTO or T_2O while residual tritium is very small, less than 0.02%. Varying the sweep gas composition has a dramatic effect on the form of tritium released. With a quartz extraction tube during post-irradiation heating, a He sweep gas results in 10-30% release as HT or T_2. CRNL-fabricated $LiAlO_2$ behaved similarly to that from ANL in these tests. Further CREATE testing has been performed using $LiAlO_2$ from France and Li_2O from Japan, under the BEATRIX international breeder exchange matrix; data analysis is underway.

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The first vented test at Chalk River, CRITIC-1, will examine ANL-fabricated Li_2O, 0.3 wt% ^6Li, 30 mm ID, 40 mm OD annular pellets, in a six-month irradiation at 700-1200 K, varying the sweep gas, with on-line HT/HTO measurement. Burnup will be 0.3%. Li_2O conductivity and tritium permeation will also be measured. Start-up is scheduled for mid-1986 for this BEATRIX test. CRITIC-II is scheduled to test CRNL-fabricated $LiAlO_2$ spherepac in 1987; French $LiAlO_2$ will be irradiated under BEATRIX in CRITIC-III (1988).

Most neutronics effort has been in support of the CRITIC experiments in NRU, and blanket modelling has also been completed. In NRU tests, tritium production will occur almost exclusively from thermal neutron captures by ^6Li. In a fusion reactor, tritium will be generated from captures, by both ^6Li and ^7Li, of neutrons within a wide energy range, 0-14 MeV. In both cases, helium will also be produced, and the stoichiometry of the ceramic will change. The average tritium production rate per gram of ceramic in a blanket will not be far different from the rate in NRU. However, in a breeder material in a fusion reactor, displacement damage from energetic neutrons will be larger than in NRU. Near the first wall of a fusion reactor, the displacement damage rate will be larger by up to two orders of magnitude, near the blanket rear, it will be comparable. A transport calculation (P_3S_8) using the 1-D XSDRNPM code was performed on a helium-cooled Li_2O blanket; natural ^6Li enrichment (7.5 at %) was assumed for the breeder blanket. The blanket tritium breeding ratio and energy multiplication were calculated to be 1.19 and 1.3, respectively. These values are in close agreement with reported values for this particular blanket.

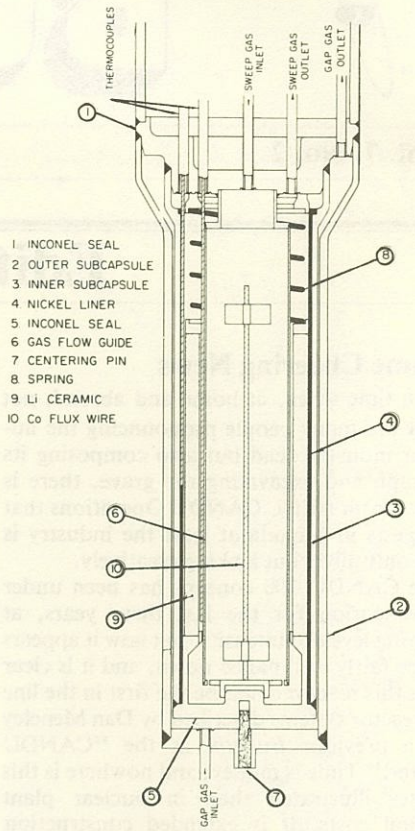

Figure 1 CRITIC - I vented capsule assembly.

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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 $40.00 ($5.00 pour les étudiants).

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Chalk River has extensive experience in the area of nuclear ceramics. For example, the concept of high density UO_2 fuel for CANDU reactors was developed at CRNL, before being transferred to Canadian industry. Of the potential solid lithium breeder candidates, three have been selected for further consideration at CRNL: the oxide, the beryllate, and the aluminate. Lithium oxide has the highest lithium density and so is the most desirable from a breeder standpoint. The main problem with the oxide is its high affinity for water vapour; any processing or handling must be performed in a glovebox with good atmospheric control. The beryllate is attractive because of its potential for neutron multiplication, but a potential technological drawback is its low melting point. Perhaps the biggest challenge of the beryllate from a fabrication development standpoint is its toxicity, which makes glovebox operations a necessity.

Lithium aluminate is probably the most preferred compound next to the oxide at the present time. It does not have as high a lithium density but is easy to work with in a normal laboratory environment. Effort was focused on this compound because it was important to acquire as much experience in as short a time as possible on the behaviour of lithium ceramics, and to make rapid progress in the development of certain novel fabrication concepts.

Most solid breeder materials have been made in the form of pellets pressed from powders. In the case of aluminate, the powder is commonly made by decomposing the carbonate in the presence of alumina. Recently, advantages have been cited for fuel in the form of microspheres (spherepac), and several approaches by other investigators have been pursued in that direction. At CRNL we are investigating powder approaches for fabricating pellets, and both powder and sol-gel approaches for making microspheres. There is significant prior experience in this area from our work on fission fuels. The pellets from commercially-available powder have been delivered to CEN-Saclay as part of the CRNL contribution to the BEATRIX program. The pellets have also been irradiated at CRNL.

Rotary agglomeration is a promising novel method of preparing microspheres from powders whereby a suitable powder is agglomerated into microspheres by tumbling; microspheres about 2 mm in diameter have been produced. Sintered densities are 65-70% of theoretical. This approach to making microspheres is unique within the breeder blanket fabrication community; preliminary results have been encouraging.

A major problem with using commercial powders sold only for their chemical purity is that physical properties such as particle size, particle morphology, and surface are not controlled or even consistent. These properties determine the properties of the product. Thus it is important to be able to synthesize the aluminate such that the powder has the physical properties desired, and work has been progressing in this direction.

The CRNL approach to the sol-gel formation of microspheres is to use the lithium in a form that is soluble in a aqueous medium but not in an organic one such as alcohol. The aluminum component is hydrolyzed to a sol and then gelled into the microsphere form in alcohol. This is accompanied by the simultaneous precipitation of the lithium component contained with the gelled alumina structure. At present microspheres of pure alumina have been prepared. This work has provided valuable information on sol formation and microsphere gelation characteristics. Work has started to introduce the lithium component, with the oxalate and formate having been selected as candidates for the starting lithium compound.

In lithium compound chemistry, evaluation of the practicality of various chemical exchange systems for lithium isotope separation is predicted upon measurement of two key experimental parameters, K_{dist} and α. K_{dist} is the distribution coefficient of a given lithium salt between two immiscible liquid phases, and is calculated from the equilibrium concentrations of the salt in the two phases. The isotopic separation factor, α, gives the extent of isotope fractionation between the same phases for a single stage; it is determined from the equilibrium $^6Li/^7Li$ ratio for the salt in each phase.

Lithium concentrations are usually obtained for solutions by atomic emission or atomic absorption spectroscopy, and lithium isotope ratios by mass spectrometry. Alternatives to these methods have been examined, in an attempt to find more efficient means of analysis. A simple procedure based on a commercially available cation-specific electrode and pH/mV meter has been developed for measurement of lithium ion concentration in aqueous solution. A good calibration curve is achieved over the $[Li^+]$ range $1x10^{-5}$ to 1 mol/L; sample analysis time is less than five minutes, and accuracy/precision are comparable to or better than ICP-AES over this concentration range ($\pm$ 1-2%). Because lithium-specific electrodes are not yet available, other cations like Na^+ or K^+ are interferences. Therefore this procedure is only applicable to lithium solutions containing negligible concentrations of other cations. Only a few lithium salts are suitable for analysis of the $^6Li/^7Li$ ratio by mass spectometry. At CRNL all lithium samples must be converted to LiF, and interfering organic contaminants must be removed by chemical oxidation. In the search for a more convenient method we have been looking at nuclear magnetic resonance (NMR) spectroscopy. Both ^6Li and ^7Li produce a signal, so that coaxial solutions containing an isotopic standard and the unknown sample, respectively, can provide a ^6Li and a ^7Li spectrum. Current tests are being done to determine the limiting precision and accuracy obtainable by this technique.

In fundamental material studies, the three main accelerator facilities at CRNL that have been used for implanting heavy ions are a 70 kV mass separator, a 2.5 MV mass separator and a 2.5 MV Van de Graaff accelerator. Using various heating and cooling stages, the sample temperature can be varied from 35-770 K. Facilities are also available for sweeping the ion beams over the target, thus resulting in uniform implantation over areas up to ~1 cm^2.

In one test series, HT^+ and DT^+ ions have been implanted into polycrystalline sintered samples of Li_2O and $LiAlO_2$ and into single crystal Li_2O. Ion energies varied from 10 keV to 50 keV and ion doses were in the range 10^{19}-$5x10^{20}$ ions/m^2. Elastic recoil detection, ERD (using 2 MeV α-particles), and thermonuclear reaction analysis, TRA ($T(d,\alpha)n$ reaction at E_d = 0.25 MeV) were used to obtain tritium depth profiles. The ERD technique was suitable for profiling tritium at small depths (0.1-0.2 μm) below the surface, while the TRA technique was best for deeper profiling (0.5-1.0 μm); in both cases the sensitivity was ~10^{19} T atoms/m^2. The diffusion of implanted tritium was followed as a function of temperature up to 800 K and the data obtained are compared with other tritium retention studies. In addition, the ERD technique was applied to study depth profiles of H and D upon exposure to H_2O and D_2O, after prolonged ion bombardment, and as a function of annealing time and temperature.

A major effort has been associated with the Tandem Accelerator Super-conducting Cyclotron (TASCC). A cryogenic target chamber for light ion irradiation (proton, deuteron, He) has been constructed and incorporated into the beam line of the TASCC and an energy range of 15-22 MeV has been chosen because it best simulates the energy spectrum of the primary knock-on atoms produced by 14 MeV neutrons. The most common problem associated with ion irradiation, especially at cryogenic temperatures, is beam heating. To minimize this, the specimens are immersed in a low pressure helium cooling gas (~0.1 Pa). The ion beam is swept over a length of 2.5 cm using a sweeping magnet upstream. Radiation damage is presently being determined by resistivity changes, but in future it will be monitored by measuring simultaneously resistivity and the length of the specimen, using a scanning laser; a computerized data acquisition system is used during all stages of the experiments. A series of experiments has been performed without an ion beam to confirm the thermal characteristics of the cryostat and one preliminary test has been conducted with a 15 MeV proton beam. The helium cooling gas performed well, resulting in a temperature rise of less than 1 K at a beam current density of 10^6 nA/m^2 and a resistivity of an annealed zirconium specimen increased from 0.1 $\mu\Omega \cdot$ cm to 0.5 $\mu\Omega \cdot$ cm in the $4x10^4$ s of irradiation time. Design and construction of a new target chamber is underway, to allow use of a scanning laser, sensitive to $2.54x10^{-8}$ m, for dimensional measurements during irradiation. This will be applied to the thermomechanical behaviour of the blanket.

Additionally, irradiation with spallation neutrons at IPNS (ANL) has shown damage production, measured as a change in electrical resistivity, as a function of solute additions at 4 K. The addition of Ti, Sn, Au, and Dy in Zr all enhance damage production. Post-irradiation annealing results show all four solutes supress damage recovery, suggesting interstitial trapping. Zr with 1000 ppm Ti, Sn, and Au (each in separate samples) has also been irradiated with 14.1 MeV fusion neutrons in RTNS-II, the accelerator based D-T neutron source at Lawrence Livermore National Laboratory. Damage is opposite that from IPNS. The difference is tentatively attributed to the difference in neutron spectrum; further tests are planned.

A blanket systems element of the program has a number of tasks. There is a liquid metal breeder "watching brief," and a major review of the European program has been completed. Work has progressed on the novel RPI/Grumman/CFFTP aqueous, self-cooled blanket design, and studies of enhanced tritium production in CANDU reactors, and of organic coolant applications to fusion, have been made.

The strategy of the first three-year program has accomplished the basic objective of establishing a Canadian presence on the world scene, and the solid breeder materials route has proved most effective. The challenge of the next five-year period (1987-92) will be to steer the program into a broader range of activities, including liquid metal blankets, while preserving the basis built in the first three years. It is encouraging that many of the topics identified by the US FINESSE study (with international co-operation) on directions of fusion technology are already components of the Chalk River program: advanced tritium recovery experiments; effects of burnup, material, and sweep gas on tritium behaviour; assessment of novel materials (e.g. beryllates); and fabrication development. The long-range goal for the program, with the expertise acquired in other CFFTP programs, is to put in place the Canadian capability for a total fusion fuel cycle package.

I.J. Hastings

FYI

Uranium Notes (R.T. Whillans)

The section, Uranium Notes, to be a regular feature of the Bulletin, is compiled by Bob Whillans from the Uranium and Nuclear Energy Branch of the Department of Energy Mines and Resources.

In 1985, production from Canada's five primary uranium producers was an estimated 10 870 tU, compared to 11 170 tU in 1984. Shipments of primary uranium were estimated at 10 029 tU, valued at $960 million, compared to final shipments for 1984 of 10 272 tU valued at $902 million. Some 55 per cent of Canada's total uranium production and shipments in 1985 was attributable to the three Saskatchewan operations, the balance coming from the two producers at Elliot Lake, Ontario.

On September 26, 1985, the United States Secretary of Energy announced that he had determined the domestic uranium industry to be non-viable, thereby triggering an investigation by the U.S. Trade Representative (USTR) with a view to assessing the feasibility of imposing trade restrictions. Throughout 1985 the U.S. uranium industry exerted strong pressure to limit imports of uranium into the United States. In his December 26, 1985, response to the Secretary of Energy, the USTR recommended against taking any import restraint measures. However, it is anticipated that there will be continued effort on the part of the U.S. industry, probably through the legislative route, to impose restrictions on the import of foreign uranium.

A survey of Canadian uranium producers indicates that the average price under all export contracts made by these firms for deliveries in 1985 was $Cdn 92/Kg U, up marginally from the 1984 figure of $Cdn 90/kg U. Applying the average U.S. dollar conversion rate, the Canadian export price for 1985 is equivalent to $US 25.80/lb U_3O_8, well above the average 1985 NUEXCO Exchange Value of $US 15.60/lb U_3O_8. Once again the spot market had a significant impact on the average price, as some 19 per cent of export deliveries in 1985 were under spot sales, compared with 25 per cent in 1984, 10 per cent in 1983 and only 1.5 per cent in 1982.

Pickering-8 Starts Up (Staff)

The eighth and final nuclear reactor at the Pickering Nuclear Generating Station, east of Toronto, went critical on December 17th and was synchronized to Ontario's electricity grid on January 21st.

This increases the total capacity of the station to over 4,000 megawatts, with all units running. On the day that unit 8 began its nuclear reaction, Ontario's total electrical demand exceeded 20,000MW for the first time.

Construction at Pickering first began twenty one years ago in 1965, on the first two commercial CANDU reactors, Pickering 1 & 2, which entered service in 1971. These units are currently undergoing retubing, with the same improved pressure tubes made of zirconium niobium alloy which all subsequent reactors have. Pickering 1 is due back in operation in February 1987 and Pickering 2 is due back in May 1987.

The total initial capital cost of the first four units (Pickering A) was $746 million, and the total initial capital cost of the last four units (Pickering B) is estimated at $3.8 billion. The unit costs of nuclear generated electricity remain below the costs of comparable coal generated electricity. Ontario Hydro's nuclear generation is estimated to have saved over $2 billion in coal costs from 1971 to 1984.

Pt. Lepreau II Talks End (Wall Street Journal)

New England utilities and the New Brunswick Electric Power Commission broke off talks on the Canadian proposal to build a second nuclear plant at Point Lepreau and sell the output to the US, in January.

"We just haven't been able to get all the things in place," said Lin Titus, Assistant General Manager of the New Brunswick Electric Power Commission. The Commission had hoped to sign agreements to sell the power with guarantees that the Canadian federal government, rather than the New England or New Brunswick utilities, would absorb possible construction cost overruns. Last month, New Brunswick negotiators told their New England counterparts that the federal government wasn't likely to back that arrangement.

Titus said New Brunswick will seek other ways to finance a second unit, but for now will pursue an extension of its agreement to sell power from the existing nuclear plant at Point Lepreau. Under that agreement, which expires in 1991, New England utilities buy 36.5% of the output from the 630,000 kilowatt plant.

Group to Investigate US Nuclear Waste Sites (Staff)

A group of federal and provincial officials has been formed to plan a response to a recent US Department of Energy selection of 12 sites in 7 states in the eastern US as possible locations for a second underground nuclear waste repository. Eight more sites as backup locations were also announced, and final selection is expected in the 1990s after further research.

The group will examine legal, diplomatic and technical aspects of the US plan for the sites chosen near the Canadian-US border in the states Minnesota, Wisconsin, New Hampshire and Maine. Assurances have already been given to Canada that the ultimate dump site will pose no hazard.

The three states Nevada, Texas and Washington State were earlier chosen as contenders for the first nuclear waste repository site.

Manitoba Allows Groundwater Study (Staff)

The Manitoba Government has given permission to Atomic Energy of Canada Ltd. to carry our a 15 year hydrogeological study of a 15 square kilometre area surrounding the Underground Research Laboratory being constructed near Pinawa. The study will assist AECL in developing technology for the underground disposal of nuclear waste. Gauges to be installed will measure rainfall, and water flow in deep boreholes around the large underground rock formation there. Similar research is being con-

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The major irradiation testing facility at CRNL is the NRU research reactor. NRU has the capability for two types of irradiation tests to evaluate solid breeder ceramics. The unvented capsule tests, designated CREATE (**C**halk **R**iver **E**xperiment to **A**ssess **T**ritium **E**mission), are those that do not have tritium release instrumentation (thermocouples and flux detectors can be included). Tritium release information is obtained after the irradiation is complete, and the capsule is removed from the reactor. These tests can measure the interaction between the ceramic and the cladding material; also pellet swelling, cracking, and grain size and pore size changes can be observed, as well as the amount of tritium remaining in the ceramic. Information is obtained on the form of tritium released, as a function of capsule material and sweep gas. Maximum sample size is 2 cm diameter and 15 cm long, but typically, samples weighing 50-100 mg are cut from sintered pellets of the ceramic for irradiation. Each sample is vacuum-annealed in a quartz tube, and sealed in the tube for irradiation without further exposure to air, then irradiated for 48 h at an estimated temperature of less than 370 K. The maximum flux is $4x10^{18} n \cdot m^{2} \cdot s^{-1}$ (thermal) and $7x10^{17}$ $n^{2} \cdot m^{2} \cdot s^{-1}$ (>1 Me V). The free tritium recovered at room temperature is measured, as well as the isothermal tritium release at the post-irradiation test temperature; both tritiated water and reduced tritium are determined. The tritiated water may include T_2O and HTO, and the reduced tritium T_2 and HT. Both He and He-1% H_2 are used as sweep gases at a flow of 0.5 L/min, with oxygen and moisture contents of the purified gas less than 1 μL/L and extraction vessels constructed from quartz, stainless steel, Inconel-600 and nickel are available. All post-irradiated tests are performed at 873 K for 4 h; tritium remaining in the ceramic after annealing is determined by liquid scintillation counting. Four tests on $LiA1O_2$ and Li_2O in the CREATE series have confirmed that, under reducing conditions (He-H_2 sweep), most of the tritium (>70%) is released as HT or T_2; the balance as HTO or T_20 while residual tritium is very small, less than 0.02%. Varying the sweep gas composition has a dramatic effect on the form of tritium released. With a quartz extraction tube during post-irradiation heating, a He sweep gas results in 10-30% release as HT or T_2. CRNL-fabricated $LiA1O_2$ behaved similarly to that from ANL in these tests. Further CREATE testing has been performed using $LiA1O_2$ from France and Li_2O from Japan, under the BEATRIX international breeder exchange matrix; data analysis is underway.

The vented capsule tests, designated CRITIC (**C**halk **R**iver **I**n-Reactor **T**ritium **I**nstrumented **C**apsule) permit continuous in situ monitoring of the tritium release from the ceramic during the irradiation, by passing a sweep gas around or through the ceramic and into an analysis train. The form of tritium is also determined. Since fusion reactors will use a sweep gas to recover the tritium in the same way, the experiment attempts to model a miniature segment of a blanket. Figure 1 shows a diagram of the CRITIC assembly. A sample size 4 cm diameter by about 10 cm long is possible in the current capsule, typically in the form of sintered pellets, with about 20% porosity. The capsule provides approximately uniform ceramic temperatures to facilitate analysis of release data; a small radial temperature gradient of about 50 K enables calculation of thermal conductivity of the ceramic. The temperature is adjustable between 400 K and 1200 K (the expected range in a commercial reactor) by varying the composition of an insulating gas layer (gap gas). In addition to on-line tritium analysis, gamma spectroscopy monitors the release rate of trace quantities of other radioactive species resulting from neutron activation and from fission of uranium impurities in the ceramic. A moveable spectrometer will be located at the glove box containing the tritium analysis system, and a portable spectrometer will be available adjacent to the gas line exit ports from the reactor. Other instrumentation will include thermocouples, on-line flux monitors, and integrated flux monitors. Analysis of the gap gas also permits measurement of the permeation rate of tritium through the Inconel capsule wall.

The first vented test at Chalk River, CRITIC-1, will examine ANL-fabricated Li_2O, 0.3 wt% ^{6}Li, 30 mm ID, 40 mm OD annular pellets, in a six-month irradiation at 700-1200 K, varying the sweep gas, with on-line HT/HTO measurement. Burnup will be 0.3%. Li_2O conductivity and tritium permeation will also be measured. Start-up is scheduled for mid-1986 for this BEATRIX test. CRITIC-II is scheduled to test CRNL-fabricated $LiA1O_2$ spherepac in 1987; French $LiA1O_2$ will be irradiated under BEATRIX in CRITIC-III (1988).

Most neutronics effort has been in support of the CRITIC experiments in NRU, and blanket modelling has also been completed. In NRU tests, tritium production will occur almost exclusively from thermal neutron captures by ^{6}Li. In a fusion reactor, tritium will be generated from captures, by both ^{6}Li and ^{7}Li, of neutrons within a wide energy range, 0-14 MeV. In both cases, helium will also be produced, and the stoichiometry of the ceramic will change. The average tritium production rate per gram of ceramic in a blanket will not be far different from the rate in NRU. However, in a breeder material in a fusion reactor, displacement damage from energetic neutrons will be larger than in NRU. Near the first wall of a fusion reactor, the displacement damage rate will be larger by up to two orders of magnitude, near the blanket rear, it will be comparable. A transport calculation (P_3S_8) using the 1-D XSDRNPM code was performed on a helium-cooled Li_2O blanket; natural ^{6}Li enrichment (7.5 at %) was assumed for the breeder blanket. The blanket tritium breeding ratio and energy multiplication were calculated to be 1.19 and 1.3, respectively. These values are in close agreement with reported values for this particular blanket.

Chalk River has extensive experience in the area of nuclear ceramics. For example, the concept of high density UO_2 fuel for CANDU reactors was developed at CRNL, before being transferred to Canadian industry. Of the potential solid lithium breeder candidates, three have been selected for further consideration at CRNL: the oxide, the beryllate, and the aluminate. Lithium oxide has the highest lithium density and so is the most desirable from a breeder standpoint. The main problem with the oxide is its high affinity for water vapour; any processing or handling must be performed in a glovebox with good atmospheric control.

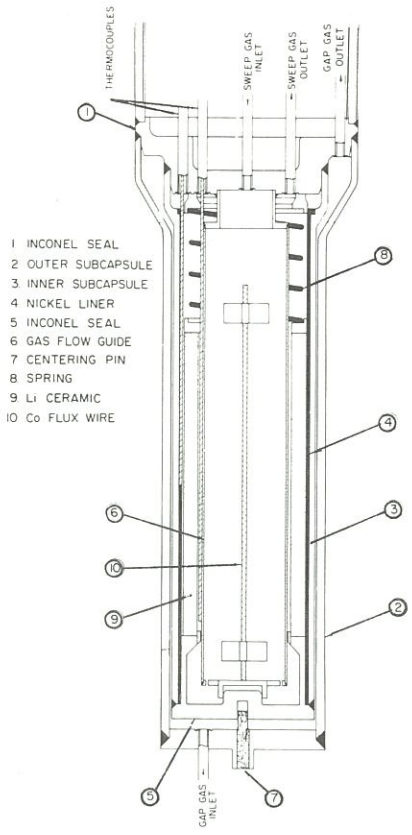

Figure 1 CRITIC - I vented capsule assembly.

The beryllate is attractive because of its potential for neutron multiplication, but a potential technological drawback is its low melting point. Perhaps the biggest challenge of the beryllate from a fabrication development standpoint is its toxicity, which makes glovebox operations a necessity.

Lithium aluminate is probably the most preferred compound next to the oxide at the present time. It does not have as high a lithium density but is easy to work with in a normal laboratory environment. Effort was focused on this compound because it was important to acquire as much experience in as short a time as possible on the behaviour of lithium ceramics, and to make rapid progress in the development of certain novel fabrication concepts.

Most solid breeder materials have been made in the form of pellets pressed from powders. In the case of aluminate, the powder is commonly made by decomposing the carbonate in the presence of alumina. Recently, advantages have been cited for fuel in the form of microspheres (spherepac), and several approaches by other investigators have been pursued in that direction. At CRNL we are investigating powder approaches for fabricating pellets, and both powder and sol-gel approaches for making microspheres. There is significant prior experience in this area from our work on fission fuels. The pellets from commercially-available powder have been delivered to CEN-Saclay as part of the CRNL contribution to the BEATRIX program. The pellets have also been irradiated at CRNL.

Rotary agglomeration is a promising novel method of preparing microspheres from powders whereby a suitable powder is agglomerated into microspheres by tumbling; microspheres about 2 mm in diameter have been produced. Sintered densities are 65-70% of theoretical. This approach to making microspheres is unique within the breeder blanket fabrication community; preliminary results have been encouraging.

A major problem with using commercial powders sold only for their chemical purity is that physical properties such as particle size, particle morphology, and surface are not controlled or even consistent. These properties determine the properties of the product. Thus it is important to be able to synthesize the aluminate such that the powder has the physical properties desired, and work has been progressing in this direction.

The CRNL approach to the sol-gel formation of microspheres is to use the lithium in a form that is soluble in a aqueous medium but not in an organic one such as alcohol. The aluminum component is hydrolyzed to a sol and then gelled into the microsphere form in alcohol. This is accompanied by the simultaneous precipitation of the lithium component contained with the gelled alumina structure. At present microspheres of pure alumina have been prepared. This work has provided valuable information on sol formation and microsphere gelation characteristics. Work has started to introduce the lithium component, with the oxalate and formate having been selected as candidates for the starting lithium compound.

In lithium compound chemistry, evaluation of the practicality of various chemical exchange systems for lithium isotope separation is predicted upon measurement of two key experimental parameters, K_{dist} and α. K_{dist} is the distribution coefficient of a given lithium salt between two immiscible liquid phases, and is calculated from the equilibrium concentrations of the salt in the two phases. The isotopic separation factor, α, gives the extent of isotope fractionation between the same phases for a single stage; it is determined from the equilibrium $^6Li/^7Li$ ratio for the salt in each phase.

Lithium concentrations are usually obtained for solutions by atomic emission or atomic absorption spectroscopy, and lithium isotope ratios by mass spectrometry. Alternatives to these methods have been examined, in an attempt to find more efficient means of analysis. A simple procedure based on a commercially available cation-specific electrode and pH/mV meter has been developed for measurement of lithium ion concentration in aqueous solution. A good calibration curve is achieved over the $[Li^+]$ range $1x10^{-5}$ to 1 mol/L; sample analysis time is less than five minutes, and accuracy/precision are comparable to or better than ICP-AES over this concentration range ($\pm$ 1-2%). Because lithium-specific electrodes are not yet available, other cations like Na^+ or K^+ are interferences. Therefore this procedure is only applicable to lithium solutions containing negligible concentrations of other cations. Only a few lithium salts are suitable for analysis of the $^6Li/^7Li$ ratio by mass spectometry. At CRNL all lithium samples must be converted to LiF, and interfering organic contaminants must be removed by chemical oxidation. In the search for a more convenient method we have been looking at nuclear magnetic resonance (NMR) spectroscopy. Both ^6Li and ^7Li produce a signal, so that coaxial solutions containing an isotopic standard and the unknown sample, respectively, can provide a ^6Li and a ^7Li spectrum. Current tests are being done to determine the limiting precision and accuracy obtainable by this technique.

In fundamental material studies, the three main accelerator facilities at CRNL that have been used for implanting heavy ions are a 70 kV mass separator, a 2.5 MV mass separator and a 2.5 MV Van de Graaff accelerator. Using various heating and cooling stages, the sample temperature can be varied from 35-770 K. Facilities are also available for sweeping the ion beams over the target, thus resulting in uniform implantation over areas up to~1 cm^2.

In one test series, HT^+ and DT^+ ions have been implanted into polycrystalline sintered samples of Li_2O and $LiAlO_2$ and into single crystal Li_2O. Ion energies varied from 10 keV to 50 keV and ion doses were in the range 10^{19}-$5x10^{20}$ ions/m^2. Elastic recoil detection, ERD (using 2 MeV α-particles), and thermonuclear reaction analysis, TRA ($T(d,\alpha)n$ reaction at E_d = 0.25 MeV) were used to obtain tritium depth profiles. The ERD technique was suitable for profiling tritium at small depths (0.1-0.2 μm) below the surface, while the TRA technique was best for deeper profiling (0.5-1.0 μm); in both cases the sensitivity was ~10^{19}T atoms/m^2. The diffusion of implanted tritium was followed as a function of temperature up to 800 K and the data obtained are compared with other tritium retention studies. In addition, the ERD technique was applied to study depth profiles of H and D upon exposure to H_2O and D_2O, after prolonged ion bombardment, and as a function of annealing time and temperature.

A major effort has been associated with the Tandem Accelerator Super-conducting Cyclotron (TASCC). A cryogenic target chamber for light ion irradiation (proton, deuteron, He) has been constructed and incorporated into the beam line of the TASCC and an energy range of 15-22 MeV has been chosen because it best simulates the energy spectrum of the primary knock-on atoms produced by 14 MeV neutrons. The most common problem associated with ion irradiation, especially at cryogenic temperatures, is beam heating. To minimize this, the specimens are immersed in a low pressure helium cooling gas (~0.1 Pa). The ion beam is swept over a length of 2.5 cm using a sweeping magnet upstream. Radiation damage is presently being determined by resistivity

changes, but in future it will be monitored by measuring simultaneously resistivity and the length of the specimen, using a scanning laser; a computerized data acquisition system is used during all stages of the experiments. A series of experiments has been performed without an ion beam to confirm the thermal characteristics of the cryostat and one preliminary test has been conducted with a 15 MeV proton beam. The helium cooling gas performed well, resulting in a temperature rise of less than 1 K at a beam current density of 10^6 nA/m^2 and a resistivity of an annealed zirconium specimen increased from 0.1 $\mu\Omega \cdot$ cm to 0.5 $\mu\Omega \cdot$ cm in the 4×10^4 s of irradiation time. Design and construction of a new target chamber is underway, to allow use of a scanning laser, sensitive to 2.54×10^{-8} m, for dimensional measurements during irradiation. This will be applied to the thermomechanical behaviour of the blanket.

Additionally, irradiation with spallation neutrons at IPNS (ANL) has shown damage production, measured as a change in electrical resistivity, as a function of solute additions at 4 K. The addition of Ti, Sn, Au, and Dy in Zr all enhance damage production. Post-irradiation annealing results show all four solutes supress damage recovery, suggesting interstitial trapping. Zr with 1000 ppm Ti, Sn, and Au (each in separate samples) has also been irradiated with 14.1 MeV fusion neutrons in RTNS-II, the accelerator based D-T neutron source at Lawrence Livermore National Laboratory. Damage is opposite that from IPNS. The difference is tentatively attributed to the difference in neutron spectrum; further tests are planned.

A blanket systems element of the program has a number of tasks. There is a liquid metal breeder "watching brief," and a major review of the European program has been completed. Work has progressed on the novel RPI/Grumman/CFFTP aqueous, self-cooled blanket design, and studies of enhanced tritium production in CANDU reactors, and of organic coolant applications to fusion, have been made.

The strategy of the first three-year program has accomplished the basic objective of establishing a Canadian presence on the world scene, and the solid breeder materials route has proved most effective. The challenge of the next five-year period (1987-92) will be to steer the program into a broader range of activities, including liquid metal blankets, while preserving the basis built in the first three years. It is encouraging that many of the topics identified by the US FINESSE study (with international co-operation) on directions of fusion technology are already components of the Chalk River program: advanced tritium recovery experiments; effects of burnup, material, and sweep gas on tritium behaviour; assessment of novel materials (e.g. beryllates); and fabrication development. The long-range goal for the program, with the expertise acquired in other CFFTP programs, is to put in place the Canadian capability for a total fusion fuel cycle package.

I.J. Hastings

(Reprinted from the CNS Bulletin, March/April 1986)

ducted in Ontario at Atikokan, Elliot Lake and Chalk River.
In related research, at the Whiteshell Nuclear Research Establishment in Pinawa, a "Large Block Radionuclide Migration Facility" is being set up, which will test the migration of radionuclides through 1x1x.6 cubic metre slabs of granite mined from the area, under laboratory conditions.

Ontario Radiation Dose Falls in 1985 (Ontario Hydro)

The average whole body dose per person at Ontario Hydro has dropped substantially since 1968, when about 900 people worked at the Nuclear Power Demonstration unit at Rolphton and the Douglas Point station, and the total whole body exposure was 899 rem.
In 1985, employees operated 12 large commercial nuclear reactors, began decommissioning the Douglas Point reactor, continued retubing Pickering reactors 1 and 2 and operated a radioactive waste management site at the Bruce Nuclear Power Development. Yet the total whole body radiation dose for Ontario Hydro's nuclear program was only 1223 rem, distributed over almost 3500 people. No one exceeded the whole body annual radiation dose limit of 5 rem set by the Atomic Energy Control Board.
In compiling these statistics, Ontario Hydro counts everyone who comes into contact with radioactivity — both regular and contract staff.

International Tokamak Agreement Reached (Nucleonics Week)

A new international agreement between the European Community (EC), the US and Japan for cooperation in the field of thermonuclear fusion research was signed at the Max Planck Institute for Plasma Physics at Garching, West Germany on January 15th. The agreement associates the three largest tokamak-type experimental fusion devices in the world: the Joint European Torus (JET) at Culham in the UK, JT-60 at Naka-Machi in Japan, and TFTR at Princeton in the US.
Cooperation is expected to take many forms: more extensive exchanges of information and researchers, the joint preparation of certain research programs, and the joint sponsorship of symposia, etc. Activities may be conducted on a trilateral or bilateral basis.

World Nuclear Electricity at 15% in 1985 (IAEA)

Nuclear energy now provides approximately 15 percent of the world's electricity and, as the number of operating plants continues to mount, the cumulative operating experience increases by more than one reactor-year daily.
So said the International Atomic Energy Agency (IAEA) in Vienna in a year-end statement. At the end of 1985, there were 374 power reactors connected to electricity supply networks in 26 countries, representing 248,577 MWe of generating capacity, the IAEA said.
In 1985, 31 new reactors (29,152 MWe), were connected to the grid and construction was started on six more (5,180 MWe), the IAEA said. Two small reactors with a combined capacity of only 250 megawatts were shut down during the year.
Notably, last year was the first since the early 1970's in which no contracted nuclear plant project was cancelled or suspended, the agency said.

Bruce Unit 2 In-Core LOCA (Staff)

On Friday March 28, pressure tube N-06 at Unit 2 of Ontario Hydro's Bruce A Nuclear Generating Station suddenly ruptured. The surrounding calandria tube also failed.
The reactor had been shut down due to an unrelated incident since mid-week. Evidence of a small pressure tube leak was detected. This leak appeared typical of the small leaks due to delayed hydride cracking in the rolled joint area previously experienced at this unit. In an effort to increase the leak rate the primary heat transport system pressure was raised. Operators then received indications of an abrupt fall in primary heat transport system pressure and a rise in moderator level, a combination of circumstances suggesting failure of a pressure tube and its surrounding calandria tube. Approximately 10 Mg of primary heat transport heavy-water entered the moderator.
Fuel has been removed from the damaged channel and inspections of the fuel bundles have revealed six of the thirteen bundles have been mechanically damaged. A total of eight and a half fuel pencils are missing from the six bundles. Two of the pencils have been located in the irradiated fuel bay.
At the time of writing Ontario Hydro is preparing to inspect the damaged channel using a miniature TV camera, over the weekend of 4-6 April.
Ontario Hydro spokesperson Mike Williams noted that higher than normal radiation fields strongly suggest that some fuel fragments have entered the calandria, a circumstance which will complicate repairs. While emphasizing that it was far too early to make any firm estimates of restart dates, current thinking was that the Unit might be shut down for "about two months."

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CNS News

1986 CNA/CNS Student Conference Report

This annual conference provides an opportunity for students of nuclear engineering from across Canada to meet their peers as well as professionals in the nuclear industry, and to exchange research information on current work in the field. Technical papers are presented covering work in progress on the students' research projects at the graduate and undergraduate level. The conference is jointly sponsored by the Canadian Nuclear Association (CNA) and the Canadian Nuclear Society (CNS), often with the added assistance of local organizations.
This year's conference was held on the campus of the University of New Brunswick in Fredericton, March 13-15, 1986, and organized by students from the Chemical and Mechanical Engineering Departments. The chairperson of the organizing committee was Judy Barr; leading committee members were Scott Boyd, Trish Cullinan, J.-F. Lafortune, Rob Leger, Mark Mosher, and David O'Connor. The University of Toronto, Ecole Polytechnique, and Trent University sent delegates; Royal Military College was prevented from attending by a federal government expense freeze.
The conference was generously supported by several organizations. In addition to student travel assistance provided by CNA, and sponsorship of the annual banquet by CNS, the New Brunswick Electric Power Commission hosted the Saturday luncheon. Financial assistance also was provided by the Students' Representative Council of UNB. Thanks are due to the three judges of student papers, Roger Steed and Georges Comeau of Point Lepreau Generating Station and Dave Wilson of Atlantic Nuclear Services.
Friday's activities included a workshop with the title "Public Perceptions of the Nuclear Industry." Dr. Bob Andrews of Chalk River

Nuclear Laboratories, Dr. Terry Thompson of NB Power, and Professor Derek Livesey of the UNB Physics Department served as panel members. Each discussed different aspects of the problem of public communication and education. In the afternoon a field trip to Point Lepreau station was joined by several students attending the Eastern Region student conference of the Canadian Society for Chemical Engineering, which was held concurrently with this conference. The evening banquet was addressed by Mr. Arthur O'Connor, general manager of NB Power. Mr. O'Connor presented a clear and informative talk on future prospects for nuclear energy in New Brunswick.

Saturday was devoted to presentation of ten graduate and five undergraduate papers. The quality of papers and their presentation was very high, and a credit to the work of the students who presented them. Graduate paper awards were presented to Marcello Mastroianni of the University of Toronto, Anthony Cancilla of the University of Toronto, and Jean-Francois Lafortune of UNB. Undergraduate awards were won by Mark Mosher of UNB, Walter Kraus of U of T, and John Lash of U of T. The treacherous March weather of the Maritimes took its toll; Mr. Jon Jennekens, president of the Atomic Energy Control Board, was prevented from presenting his scheduled luncheon address. On the other hand, Mr. Jennekens gained the opportunity of taking a grand tour of the maritimes, including an overnight stop in Halifax. His aircraft eventually touched down in the snow of Fredericton about the time the conference ended. Many thanks are due to Mr. Jennekens for a gallant effort, and apologies are offered to him for our inhospitable weather.

All students were so keen on their studies that it was difficult to get them to break away for a bit of relaxation. A few did, however, find time to join the chemical engineers for a tour of some of the bright spots of Fredericton. Laval University showed their mettle by winning the boat race.

The general conclusion was that this conference was a great success both technically and socially.

D.A. Meneley

PRV

The following letter by Larry Leonoff, Ontario Hydro's General Counsel and Secretary, is in response to a fund-raising letter written on behalf of Energy Probe (a Toronto-based lobby group) by novelist Margaret Laurence. Ms. Laurence's letter focused on Ontario Hydro's plan to market tritium, and linked this plan with nuclear weapons production. As he notes in his letter, Mr. Leonoff's response is individual, and represents nobody's opinion but his own.

Ms. Margaret Laurence
c/o Energy Probe
100 College Street
Toronto, Ontario
M5G 9Z9

Dear Ms. Laurence:

I received a personnally addressed copy of your recent mailing asking for funds for your organization along with your letter dealing with the tritium issue. I wish to make it quite clear before this letter goes any further that I am writing to you on a personal basis and not as General Counsel and Secretary of Ontario Hydro. The comments contained in this letter are my own and do not necessarily represent the views of the Corporation nor of any of its officers.

Your letter, in my view, is a personal attack on me and my colleagues. I make this statement because the Corporation is run by its decision-makers and I am fortunate to be one of those decision-makers. Even though my name is not mentioned in your correspondence, it nevertheless logically follows from your words that those individuals who will make the final decision on the tritium issue are acting in a dishonest manner and are conniving through the ruse of a public participation program designed to placate the public when all along the decision to export tritium has already been made. This statement is a gross distortion of the truth. As someone who has passionately wrestled with the pros and cons of this difficult issue and has been personally involved in many high level meetings with free, spirited dialogue on both sides of the issue, I know that the final disposition of this matter has not been prejudged and the public participation program is a sincere attempt on the part of the Corporation to receive input from different segments of society.

The Board of Directors and the executives of Ontario Hydro invited you and your colleagues as our guests to come to a meeting in our Board Room. During that meeting we listened with open minds to what you had to say. We took your criticism of the study seriously and we asked those who prepared the study to respond to your allegations that some of the statements in the study were misleading. We acted, in my opinion, in a responsible manner and we continue to act so. Your organization, on the other hand, has responded in a manner which I can only describe as showing extreme lack of integrity. Your mailing is filled with distortions, innuendoes and false assumptions. You have taken the proceedings of our private meeting and have twisted it to suit your purposes.

Your organization does not have the exclusive right to speak for all the truth and justice in the world. My colleagues and I are also concerned with world peace and stability. Your organization should realize that caring, rational people can have different views than those of Energy Probe and could be right on occasion.

I happen to be personally opposed to the sale of tritium, but I reject the dishonest approach your organization is taking on this issue. Whatever decision the Corporation makes, the issues and arguments which lead to the final disposition of this matter should be dealt with on its merits and not drowned in a sea of false rhetoric and distortion. Personally, I will continue to treat this issue on its merits. I can only trust that my collagues will take the same attitude.

Whatever the outcome of this matter, I for one, will not forget this incident and if at any time in future years the question of the integrity of Energy Probe comes up, I will be the first to remind those around the table of this sordid incident.

Yours truly,
L.E. Leonoff

CNS Branch Programs

Toronto Branch News

What Hydro Plans after Darlington

The following Branch meeting report should have appeared in the last issue of the Bulletin but somehow went astray between the editor's disk and the printer. We apologise to the author for its late appearance

A 2.5 percent annual growth rate in electrical demands means post-Darlington electrical generating capacity will not be required until 1998. But if the growth rate is 3.5 percent a year, then that capacity will be required six years earlier — in 1992, the year the final Darlington Unit enters service.

In the last few years the annual growth in electrical demand in Ontario has been about 5 percent. These figures were at the heart of a talk given by Ken Snelson, Ontario Hydro's Assistant to the Director of System Planning, to the Toronto Branch, February 4. Mr. Snelson noted that the actual megawatt increase in electricity demand in Ontario over the last three years was the highest in any three-year period in Ontario Hydro's history, and while a portion of this increase might be attributable to economic rebound from the recession, it was nevertheless an impressive figure. With the construction lead-times required, Mr. Snelson pointed out, it was clear that planning to meet the electrical demands of the post-Darlington era must begin now.

Mr. Snelson examined a number of ways to meet future demands, including load management, conservation, alternative energy developments, purchases from other provinces and the traditional hydraulic, fossil-fired and nuclear installations. Comparing the last three options, Mr. Snelson noted that for a hydraulic installation, 97 percent of the total cost (capital and operating) represented dollars spent in Ontario. For nuclear installations the figure was 93 percent, while for coal-fired generation it was

only 30 percent — this principally due to the cost of imported fuel. Clearly, Mr. Snelson said, this gave Ontario Hydro a strong incentive to rely more heavily upon hydraulic and nuclear power.

Theoretically, Ontario Hydro could develop 9,700 MW of additional hydraulic power (about 3,000MW continuous) but, Mr. Snelson pointed out, engineering and economic considerations meant that realistically future hydraulic development would be limited to about 2,700MW peak (680MW continuous. Importing electricity from other provinces was an option limited, Mr. Snelson warned, by the long lead-times necessary for the construction of the appropriate transmission facilities.

In the near-term, solar and/or wind energy could make a practical contribution only where these sources might be used to substitute for diesel generated electricity in remote communities, Mr. Snelson said, and cogeneration or waste incineration contributions would also be limited.

Mr. Snelson concluded by re-affirming Ontario Hydro's commitment to the nuclear option, pointing out that with the Darlington station completed, over 60 percent of Ontario Hydro's generating capacity will be nuclear and adding, in response to a question about the danger of putting too many eggs into one basket, that it would be foolish not to back a winner. Ontario Hydro, Mr. Snelson said, provides its customers with electricity at one of the lowest rates in North America, and with the continued support of industry, governments and the various research institutions, Ontario will maintain this vital competitive edge into the twenty-first century.

Eva Hampton
John Marczak

Conferences & Meetings

12th Simulation Symposium on Reactor Dynamics and Plant Control

Sponsored by the CNS NSED, to be held **April 21-22, 1986** in Hamilton, Ontario. For information contact: **W.J. Garland, Dept. of Engineering Physics, McMaster University, Hamilton, Ontario, L8S 4M1.**

4th European Nuclear Conference and 9th FORATOM Congress (ENC) '86)

Sponsored by European Nuclear Society et al., to be held **June 1-6, 1986** in Geneva, Switzerland. For information contact: **V. Wertmueller, ENS, Baerenplatz 2, P.O. Box 2613, CH-3001 Berne, Switzerland.**

CNA 26th Annual International Conference

To be held **June 8-10, 1986** in Toronto, Ontario. For information contact: **CNA, 111 Elizabeth St., 11th Floor, Toronto, ON M5G 1P7.**

CNS 7th Annual Conference

To be held **June 8-10, 1986** in Toronto, Ontario. For information contact: **CNS, 111 Elizabeth St., 11th Floor, Toronto, ON M5G 1P7.**

Symposium on Advanced Nuclear Services

Sponsored by CNA, to be held **June 11, 1986** in Toronto, Ontario. For information contact: **CNA, 111 Elizabeth St., 11th Floor, Toronto, Ontario, M5G 1P7.**

Annual Meeting of the American Nuclear Society

To be held **June 15-19, 1986** in Reno, Nevada. For information contact: **T.C. Halverson, ANS, 555 N. Kensington Ave., La Grange Park, Il 60525.**

4th International Conference on Emerging Nuclear Energy Systems (ICENES 4)

Sponsored by the Spanish Nuclear Society, CNS, ANS, et al., to be held **June 30 - July 4, 1986** in Madrid, Spain. For information contact: **G. Velarde, Director, Dept. of Nuclear Energy, ETS Ingenieros Industriales, Universidad Politecnica de Madrid, P. de la Castellana No. 80, 28046 Madrid, Spain.**

Second International Conference on Radioactive Waste Management

Sponsored by CNS, cosponsored by ANS, to be held **Sept. 7-11, 1986** in Winnipeg, Manitoba. For information contact: **T.S. Drolet, Conference Registration Chairman, CFFTP, 2700 Lakeshore Rd. W., Mississauga, Ontario, L5J 1K3.**

International Topical Meeting on Waste Management and Decontamination and Decommissioning

Sponsored by ANS, cosponsored by CNS, US DOE, et al., to be held **Sept. 14-18, 1986** in Niagara Falls, NY. For information contact: **Eva Rosinger, AECL, 275 Slater St., Ottawa, ON K1A 0S4.**

Topical Meeting on Advances in Reactor Physics and Safety

Sponsored by ANS, EPRI, NRC and CNS, to be held **Sept. 17-19, 1986** in Saratoga Springs, NY. For information contact: **D.R. Harris,Department of Nuclear Engineering, Rensselaer Polytechnic Institute, Troy, NY 12180-3590.**

International Topical Meeting on the Operability of Nuclear Power Systems in Normal and Adverse Environments

Sponsored by ANS, cosponsored by CNS et al., to be held **Sept. 29 - Oct. 3, 1986** in Albuquerque, NM. For information contact: **L.L. Bonzon, Division 6446, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185.**

International Conference on CANDU Fuel

Sponsored by CNS, to be held **Oct. 6-8, 1986** in Chalk River, Ontario. For information contact: **Dr. I.J. Hastings, AECL Research Co., Chalk River, Ontario K0J 1J0.**

CNS 2nd International Conference on Simulation Methods in Nuclear Engineering

Sponsored by CNS NSED, to be held **Oct. 14-16, 1986** in Montreal.For information contact: **D. Rozon, GAN, Ecole Polytechnique, 6600 Côte-des-Neiges, Suite 215, Montréal, Quebec, H3S 2A9,** (514) 340-4201.

Uranium Mine Radiation Safety Course

Sponsored by Canadian Institute for Radiation Safety, to be held **Oct. 20-24, 1986** in Elliot Lake, Ontario. For information contact: **CAIRS, 7 Timmins Rd., Suite 7-15, Elliot Lake, Ontario, P5A 2R7.**

Water Chemistry & Materials Performance Conference

Sponsored by CNS, to be held **Oct. 21, 1986** in Toronto, Ontario. For information contact: **N.A. Graham, Westinghouse Canada Inc., Dorset St. E., Port Hope, ON L1A 3V4,** (416) 885-4537, ext 297.

International Symposium on Radiation Protection in Mines

Sponsored by the Chinese Nuclear Society, to be held **November 9-15, 1986** in Beijing. For information contact: **Chinese Nuclear Society, P.O. Box 2125, Beijing, China.**

International Topical Meeting on Remote Systems and Robotics in Hostile Environments — Call for Papers

Sponsored by the American Nuclear Society, cosponsored by the Canadian Nuclear Society, the Atomic Energy Society of Japan, and others, to be held **March 29-April 2, 1987,** in the Red Lion Motor Inn, Pasco, Washington. The program for this meeting will focus on the development and application of remote systems and robotics within a broad range of hostile environments. Papers addressing conventional remote systems, automation robotics, human factors, instrumentation and control, management perspectives, economics, maintenance, vision systems/sensors, and other considerations in the nuclear, underwater, space, construction, mining, military, fire-

fighting, bomb disposal, toxic chemicals, hazardous manufacturing, security, and other industries are invited. Deadline for submission of 450-900 word summaries: **May 15, 1986.** Author notification: **June 30 1986.** Full-paper deadline: **November 1, 1986.** Conference proceedings will be available at the time of the meeting. Summary papers and inquiries should be directed to: **James D. Berger, Technical Program Committee Chairman, International Topical Meeting on Remote Systems and Robotics in Hostile Environments, P.O. Box 928, Richland, Wash. 99352;** (509) 376-1178.

International Topical Conference on Methods and Applications of Radioanalytical Chemistry

Sponsored by American Nuclear Society, cosponsored by Canadian Nuclear Society NSE Division, et al., to be held **April 5-10, 1987** in Kona, Hawaii. The conference will focus on recent developments in radioanalytical chemistry techniques including, but not restricted to: instrumental and radiochemical activation analysis; nuclear track techniques; radiochemical separation techniques; radioisotopic tracer methodology; uranium and plutonium analysis; on-line and automated non-destructive analysis; gamma-ray and X-ray spectroscopy; and applications to environmental, biomedical and energy-related problems.

The objective is to promote an interchange of information on radioanalytical chemistry among scientists from the United States and other countries, and in particular from the Pacific Basin countries. The conference will comprise invited review papers plus contributed papers presenting original research accomplishments. The central geographical location of Hawaii constitutes an ideal site equally accessible to scientists from both sides of the Pacific Ocean. Good airline connections from Europe to Hawaii are also available. The isolated nature of Kona on the Island of Hawaii provides an excellent atmosphere for informational discussions and working groups among the anticipated 175-200 attending scientists. The full manuscripts of the presentations will be published in the Conference proceedings, probably as a special volume of the *Journal of Radioanalytical Chemistry*. For further information contact: **Robert E. Jervis, University of Toronto, Department of Chem. Eng. & Appl. Chem., Toronto, Ontario M5S 1A4,** (416) 978-3071.

The Unfashionable Side

Parallel Business

The nuclear power reactor business suffers from two major problems — public acceptance of the technology and economic survival. However the people at the Indescribable "A" Nuclear Generating Station have come up with an imaginative and innovative approach to both these questions. Recently I was lucky enough to be able to talk to my old friend Harry Albion, a senior member of this station's operating staff and, over a few drinks at the Hydride Regency Hotel's Star and Garter Spring bar, he outlined some of his company's plans for increasing public acceptance of nuclear power while, at the same time, generating some income.

"The fundamental point," Harry noted, "is that people just are not familiar enough with nuclear power stations. Well, we're going to change that. We're going to get the public into Indescribable "A" — in fact we're going to have them hammering at the doors to get in." "But," I responded, "there's nothing new about that, surely. You've been having plant tours ever since the station was built." Harry snorted contemptuously — a neat trick while drinking from a pint mug — "plant tours! Where's the attraction. All you get is some models at the information centre and a tedious walk round the station while some poor guide bombards you with facts and figures. No, what we're after is *involvement*. And we're going to get it. Take the simulator, for example."

"The simulator?"

"Yes — we're adding some more graphics to the display screens, and we're going to allow people 10 minutes on the simulator to run a unit and take care of randomly generated events — all for only $5.00."

"You're going to charge them?"

"You bet. Heaven knows how much that thing cost us. Here's a chance to recoup a bit. And each week we'll give a grand prize for the best performance. This is the video game to end all video games!"

"What else do you have planned?" I asked somewhat nervously.

"Well, you can drive the fuelling machine for two bucks and, if you get to transfer the lucky fuel bundle you get a mystery prize. We're having hay rides on the inter-bay transfer vehicle, a Synchronize the Generator competition, radio controlled model power boat regattas at the irradiated fuel bay and a mystery tour to the Unit Emergency Control Centres. And of course, every month we have a grand open day when, for a mere $10 admission fee, people can watch the off shift giving displays of traditional station athletic events, like the Race for the Parking Spot and the Plastic Suit Race. The station dramatic society will present dramatizations of Significant Event Reports, and we'll conclude with a mass display of the most famous and long-lived station activity, Abusing the Production Manager.

"But surely," I expostulated, "you can't attract enough people to make it worthwhile?"

"On the contrary" said Harry confidently, "a chap we've hired as a consultant from Canada's Wonderland assures us that by the time we've got the rotating restaurant installed on top of the ECI water storage tank and the roller coaster running from the vacuum building, we'll be turning them away by the thousands. And if it goes well enough, in a couple of years we could get completely out of this silly business of making electricity."

Ernest Worthing