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• Large Scale Nuclear Program • Pre-Licensing Advanced CANDU
• Regulatory Approach for Life Extension • Debate in Port Hope
• Heavy Water History • Meet New CNS President

Bruce Power takes a bold step

The most fascinating news of the past couple of months was the announcement from Bruce Power that they wish to begin the process to approve a site, on its Bruce project, for the construction of new reactors. (See General News, p. 39) This is the most forward step towards "new build" of any nuclear utility in North America and yet there was almost no media reaction. Is this one more example of the media propensity for only negative news when it comes to matters nuclear?

Regardless of the non-reaction (or lack of comprehension) of the media this is a bold move by Bruce Power and pre-empts Ontario Power Generation, which was directed by the Ontario energy minister in June to begin the process for new units. OPG did announce that it is beginning the Environmental Assessment for the refurbishment of the Pickering B plant.

Bruce Power has stated that it has not definitely decided to build new plants or what type they would be. This absence of a definite project will require some modification of the typical EA process, which is based on a specific project proposal. In announcing the application, the Canadian Nuclear Safety Commission implied that this difficulty has been considered and discussed with the Canadian Environmental Assessment Agency.

As the "responsible authority" under the Canadian Environmental Assessment Act, it is the CNSC who determines how the environmental assessment will be conducted. The first step is the identification of the scope of the proposed project and the factors that must be considered in the environmental assessment. It will be interesting to see how that is done in the absence of a specific project.

Given the size and nature of a new nuclear reactor and the continuing strong concern voiced by some segments of our society it is highly likely that this EA will eventually go to a panel review. That brings up frightening images of the eight-year "Seaborn" panel on the deep geologic nuclear waste repository. Fortunately, the government has issued guidelines for the "timely" processing of environmental assessments, which undoubtedly will have to be applied in the case of a new nuclear plant.

It is a long road ahead but Bruce Power should be applauded for taking this first bold step. The future of nuclear power in Canada (at least Ontario) seems more assured than ever.

Fred Boyd

In This Issue

We begin this issue with a letter questioning an omission in the one technical article of the June 2006 issue, *Nuclear Fission Fuel Can be Considered as Inexhaustible,* and a response from the author.

Then there are four papers selected from the many presented at the 2006 CNS Annual Conference in June beginning with one on a topic related to the one above, **Transition to Large Scale Nuclear Energy,** in which current CNS president Dan Meneley examines the scale and nature of the program needed if nuclear is to replace oil as our major primary energy source.

That is followed by two papers related to the regulatory approval regime. **Pre-Licensing of the Advanced CANDU** describes the arrangement Atomic Energy of Canada Limited has with the Canadian Nuclear Safety Commission for an ongoing review of the evolving design of the ACR (and reveals that the design is not scheduled to be completed until 2008). **Regulatory Approach for Life Extension,** which gives an overview of the CNSC requirements for approval of refurbishment projects (some of which are underway).

For a change of perspective there is an interesting proposal for a small, non-power, isotope-producing reactor in, **Homogeneous Slowpoke Reactor.**

Turning to non-technical viewpoints, there is a note on the continuing controversy in an Ontario town, **A Very Public Debate: the Nuclear Industry in Port Hope,** and, to continue our penchant for history, the story of **Heavy Water at Trail, British Columbia.**

There are a number of items in the **General News** section beginning with the fascinating proposal from Bruce Power to prepare a site for new reactors. Other news items attest to the renewed activity in the Canadian nuclear power scene.

The **CNS News** section features our traditional **Meet the President** note, this time about the 2006 –2007 president of the Canadian Nuclear Society, Dan Meneley, and includes other items about the Society.

There is a page of recent **publications** of possible interest from the CNSC and the IAEA and an updated **calendar.** And, of course, there is the inimitable perspective of Jeremey Whitlock in **Endpoint.**

Your feedback is always welcomed.

Contents

~ Cover Photo ~

The photograph on the cover is one from the 1970s of the Douglas Point plant whose start-up 40 years ago is being commemorated with the installation of a historic plaque on September 27, 2006. (See CNS News, p. 45)

– Photograph courtesy of Atomic Energy of Canada Limited

Canadian Nuclear Society

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Paper Ignored Thorium

The editor

H. Douglas Lightfoot's paper "Nuclear Fission Fuel Can be Considered as Inexhaustible" (CNS Bull. 2006 June) is valuable in demonstrating that energy from nuclear fission need not be restricted by the availability of uranium. However, an omission is potentially damaging to the Canadian industry. In a word, thorium. To ignore a "Fission Nuclear Fuel" that is at least as abundant as uranium is like ignoring coal in discussing fossil fuels.

It is true that several advanced countries that have made a large investment in fuel-inefficient Light Water Reactors (LWR) are developing technically challenging Fast Breeder Reactors (FBR) as a hedge against uranium shortages. However, those with fuel-efficient CANDU reactors have a much simpler alternative. Fuelling these reactors with thorium will not "breed", i.e., will not produce quite as much fissile material as consumed, but that is an artificial target. CANDU-thorium, along with FBRs, can vastly extend the availability of nuclear fission fuels. Two resources are better than one.

W.B. Lewis should not be cited in support of FBRs. I remember his paper, "Breeders are not necessary", since this seemed an appropriate title by a lifelong bachelor. WB devoted much of his latter years to promoting the CANDU-thorium concept.

The feasibility of thorium fuel was demonstrated in early irradiations at Chalk River while India has successfully irradiated thorium fuel bundles in six CANDU-like reactors. Both CANDU-thorium and FBRs deserve support to the demonstration stage in that they would provide diversity of fuel resources and technology.

Lightfoot considers that the two main problems in converting to FBRs are building them fast enough and providing the initial fissile inventory. In reality, the foremost problem is increasing public support for current reactors, without which politicians will not make necessary commitments. Unless there are many more of these reactors there will be no need for FBRs. The next problem would be selling a radically new design to utilities that are rightly conservative. Both public and utilities would prefer a proven design with only minor change in fuel to an unproven design using combustible fuel and coolant. To some people even the "fast" in FBRs is scary.

The paper is more appropriate to the ANS than the CNS. However, even the U.S. should ponder on the fact that fuel-efficient Toyota has overtaken fuel-inefficient GM in U.S. sales. From my experience with the U.K.'s FBR before coming to Chalk River in 1957 I concluded that the FBR is a scientist's dream but an engineer's nightmare.

Overly enthusiastic promotion of FBRs can be damaging to the nuclear industry in general and CANDU in particular. I would not like to have to tell a public meeting that if they accept a CANDU they are committing themselves to an FBR later. By ignoring CANDU-thorium Lightfoot is throwing away a major advantage of the CANDU system.

We are exemplifying two fundamental engineering principles:

- If it ain't broke don't fix it, and
- KISS – Keep It Simple & Safe.

J.A.L. Robertson

Since his retirement from AECL's Chalk River Laboratory, "Archie" Robertson has remained very active in the nuclear debate. He maintains a website **www.magma.ca/~jalrober** *which contains his book* **Decide the nuclear issues for yourself** *and many of his nuclear reviews.*

A Response From The Author

Robertson makes a good point about thorium being a nuclear fission fuel. It was included in the original paper from which the Bulletin article was prepared. See Reference [1] in the CNS Bulletin paper.

To help in any discussions about nuclear fission reactor technology, I have set out the framework in which reactors will have to evolve if we are to avoid a large disruption in future energy supply:

1. Nuclear fission energy is the only source of energy that can replace fossil fuels on the scale required. The basis for this statement is given in Reference [2].
2. Clearly, today's uranium-fueled thermal reactors cannot power the world for tens of thousands of years. We can discuss what might be the best reactor technology and the best fuel but, whatever the outcome, we must have much greater nuclear fuel efficiency than current thermal reactors using uranium fuel.
3. Thermal reactors using uranium are here now and we need them now. There is some urgency to replacing fossil fuels with nuclear because oil and natural gas are moving towards scarcity. When they do, people will have to heat and cook by electricity, trains will be powered by electricity, etc. We must move to nuclear electricity eventually, so the sooner the better.

We proposed using FBRs because they offer a hundred-fold gain in fuel efficiency, they can use the waste from thermal reactors for fuel (150-200 years supply already on hand), and waste from FBRs is of concern for less than 500 years.

Any technology that can equal or better these factors must be seriously considered.

H. Douglas Lightfoot

(On behalf of W. Manheimer, D. Meneley, D. Pendergast, and G. Stanford)


It's an uphill battle.
Even if everything at your plant is working as it should, you already know you can't afford to rest on your laurels. Diligent monitoring will continually reveal discrepancies that need to be addressed in order to provide reliable service and avoid costly down time.
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Transition To Large Scale Nuclear Energy Supply

by D.A. Meneley[1]

Ed, Note: The following paper was presented at the 27th Annual CNS Conference, Toronto, Ontario, June 2006

Abstract

We can expect to see the peak of world oil production very soon. Some say that we can see that peak now in our rear-view mirrors as we drive into an oil-poor future. Natural gas already is in short supply in North America. Nuclear energy must make up the lion's share of the world's energy deficit.

This paper examines, in very general terms, the implications of today's shifting prospects for nuclear energy, as it exists today, and how those prospects might develop in the future. The time span under consideration is the remainder of the 21st century.

Introduction

During the working lives of many professionals active today, the nuclear power industry has hovered on the brink of extinction. Will people accept the technology? Who will buy the next plant, and if they buy, at what price? Will the competition get the job? Will government support pre-commercial product development? We all have asked these questions. Now, the questions are changing.

Oil supply analysts[1] agree that world oil production must decline at some time during the 21st century. Huge imports of natural gas to North America will be needed in the near future. Which projection is correct? Will new discoveries solve the problem? Will demand moderate as prices increase? Where can we find alternative energy sources on a massive scale?

Obviously, when looking at a 100-year time frame it makes no sense to propose the solution to energy supply questions. Rather than make such an attempt, the author has chosen to follow published projections as far as they go and then to make reasonable guesses at a series of development steps that can be taken to reach a defined goal at the end of this century. To some extent this process is based on a recent IAEA symposium[2] with the declared goal of looking at the future of the world nuclear industry.

History

Uranium was recognized as a vast potential source of energy from the first days after the discovery of nuclear fission[3]. Leo Szilard[4] quickly recognized its potential for both good and bad purposes.

When R&D for the nuclear-electric industry began in the 1940's and 50's one of the main concerns was the potential shortage of uranium fuel. At the time, exploration for uranium was limited and only low ore concentrations had been found. This apparent resource shortage led to intensive work on fast-spectrum reactors; indeed, the first-ever electricity production from uranium was from a fast reactor -- the Experimental Breeder Reactor (EBR1) in Idaho. During my own time of research at Argonne National Laboratory, a great deal of work centered around calculation of the breeding ratio – a figure indicative of the amount of fresh fissile material that can be produced by a fast reactor power plant.

Dr. W.B. Lewis[5] was deeply involved with the uranium supply question, both nationally and internationally. Both uranium and thorium fuel cycles were studied in detail. The latter element, of course, suffers from a lack of any naturally occurring fissile isotope so that uranium must provide the initial fuel supply. Atomic Energy of Canada (AECL) under Lewis' direction studied several other means of producing fissile isotopes, notably by accelerator-driven spallation reactions capable of producing large numbers of neutrons for subsequent capture in the abundant fertile isotopes Thorium-232 and Uranium-238.

Successful uranium exploration in the 1960's and 70's greatly increased known uranium reserves. Large ore deposits were found in Canada, the Soviet Union and Australia, along with important quantities in several other countries. The total amount of uranium in the earth's crust is immense – and yet we do not know how much recoverable ore might be found in the future. At the present time the supply-demand pendulum appears to be swinging back toward higher prices, as the demand for fresh nuclear fuel increases.

This paper is not a "hard-and-fast" plan for the future. Further, it makes no pretence toward arguing that this future conceptual plan is the only one possible, or even that it may be the preferred plan. The objective of this paper is to illustrate some of the opportunities along with a few of the hurdles that must be passed along the way, in order to realize the vision of a secure and sustainable energy supply in the future world.

The Need for Nuclear Energy

Today's world depends heavily on petroleum, both oil and natural gas. It is still an open question as to what energy source or sources can and will take over the burden once this resource is depleted. Many options are available that can

1 Engineer Emeritus, Atomic Energy of Canada Limited, Mississauga, Ontario, L5K 1B2; and 2006-2007 president of the Canadian Nuclear Society

contribute to the solution, but it appears that nuclear energy must be a major contributor[6].

There has been much talk in recent years about the "Hubbert's Peak"[7] of world oil production. According to that model, once the peak has been reached one should expect that only one half of the total resource remains to be found. Now that prices have been high and rising for 5-10 years and yet production has been decreasing over the same period, we can safely conclude that we have passed the peak of world production.

Conservation, along with a number of alternate energy supply options, has been studied for a number of years with limited success. It has slowly become obvious that nuclear energy is the only resource available today that could take over a large fraction of the world demand for oil and gas, and yet remain neither capacity nor resource limited – that is, to be "inexhaustible" or "renewable". There is enough accessible uranium to supply the total present-day demands of humanity for at least several thousand years[8].

The question "How much energy does the world need?" is the most important and most difficult question of all, and well beyond this author's capability to estimate. As a scale comparison, the total world energy demand of the World Energy Council (WEC) 'middle course' scenario in 2050 is given as about 400 million barrels per day of oil equivalent[9]. The WEC scenarios show a slowly decreasing role for coal, a large role for natural gas, and a steadily increasing contribution from solar and biomass at that time. As noted briefly in this paper there is a real possibility for using coal or biomass to manufacture synthetic transportation fuels by adding hydrogen. Nuclear energy can be used in this way to produce fuels that are fully compatible with today's transportation, heating, and other industrial systems.

Since coal and natural gas do not seem to be scarce in a world-wide context, this work concentrates on substitution of nuclear energy for oil – a commodity that is rapidly becoming scarce.

General Industrial Plan[10, 11]

Presumed world oil demand in this study is shown in Figure 1. Up to 2030, the estimate is taken from the 2005 International Energy Agency (IEA) projection[12]. Beyond that time demand is assumed, arbitrarily, to flatten out at 140 million barrels per day.

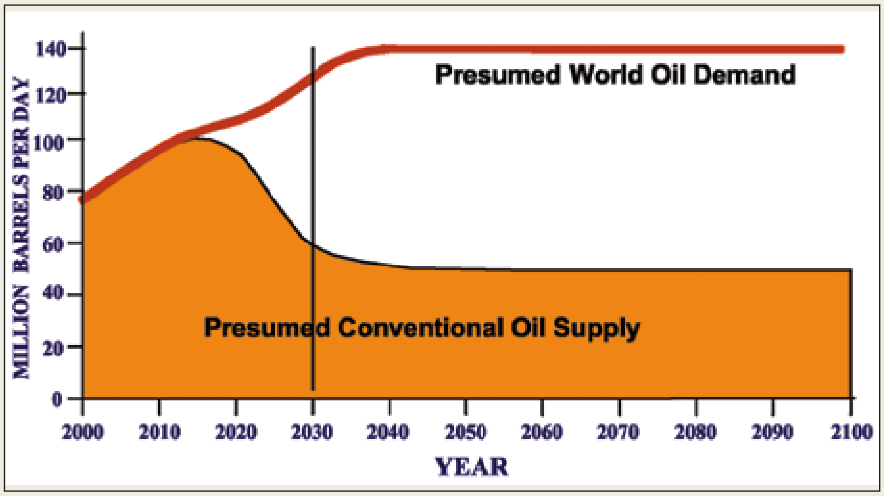

Figure 1: Presumed oil supply and demand vs. time

The supply curve for conventional oil also is taken from IEA figures up to 2030, without non-conventional supply and new discoveries. After that time supply is assumed to flatten out at 50 million barrels per day, or about half of the peak production in 2005. (Note: There is no presumption that the long-term "Supply" curve in Figure 1 is a prediction of what will happen. The essence of the question is the timing of the expected supply deficit and the fact that it will continue indefinitely into the future.) Some fraction of the deficit between conventional supply and total supply will be filled from other sources such as conservation, introduction of hybrid vehicles, new oil discoveries, wind, solar, and so on. It is important to note that the particular timing of peak world oil production is quite unimportant. It is necessary only to agree that there will be a peak of production, at some future time. In other words it is necessary only to accept the fact that recoverable oil is a finite commodity on earth.

So, what should we do about it? There have been many studies conducted, and many proposals put forward. The present-day situation has recently been summarized6, 8. These modern assessments differ little from that described in the International Institute for Applied Systems Analysis (IIASA) study carried out more than 20 years earlier[13]. The main change since the IIASA study is that the needed replacement for fossil fuels is now urgent. Nuclear energy using uranium offers the only practical answer for filling in a major part of the gap between supply and demand shown in Figure 1. Even then, the enormous scale of the replacement task cannot be over-emphasized. This is not to belittle contributions of other renewable resources and conservation. The statement is meant only to emphasize the central role of nuclear energy in any sound plan, regardless of what other partial solutions are adopted.

Substitution of nuclear fuels for fossil fuels in the supply of primary energy is not a simple task. For instance, transportation requires a portable fuel of high energy density and low weight – that is, if we choose to mimic today's pattern of transportation. The refining and distribution of fossil fuels now embodies a massive infrastructure that pervades nearly every corner of North American society. A similar complex infrastructure is seen in the electricity distribution system – it is difficult to scan the horizon in any industrial nation today without seeing some evidence of this second system. Could they/should they be combined in some way? This might increase efficiency, but might at the same time increase the system's vulnerability.

Substitution of nuclear for fossil supply can be approached in different ways. It is possible to expand the electrical distribution system and then to provide local service either for battery-powered vehicles or for some form of hybrid. The next question is whether or not batteries can be developed that can match the excellent characteristics of gasoline- and diesel-powered systems. Today's answer seems to be "not yet" though there is hope that this will be possible soon[14].

A second method of substitution is to produce

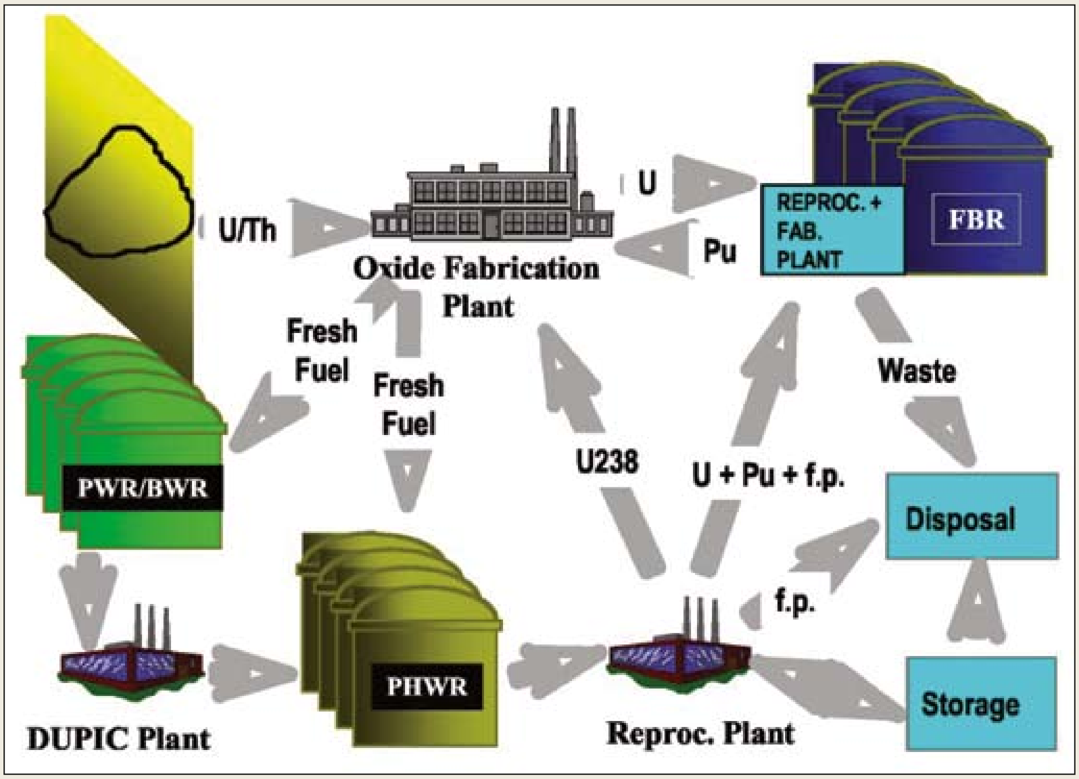

Figure 2 – Conceptual Arrangement of a Nuclear Energy Park

an intermediate energy carrier[15] such as hydrogen that can be utilized in different ways such as local night-to-day storage for peak leveling, in fuel cells, or as feedstock for manufacture of hydrocarbons. Hydrocarbon production is practiced today in South Africa[16], using an improved process relative to the basic method developed in Germany in the 1920's[17]. Production of hydrogen can be done either by direct electrolysis or by a number of alternate chemical processes. Hydrogen is particularly difficult to store and transport; local generation of hydrogen from electricity is being considered as an alternative to central generation and pipeline distribution. No single method has yet emerged as being superior to others.

Strategies for Installation of Large-Scale Nuclear Supplies

Even though there is strong evidence that the long-term nuclear future must be based on fast reactor technology, almost all nuclear plants operating in the world today are powered by thermal reactors. As a result we must consider the necessary steps in a transition from today's technologies to those appropriate for the long-term future in which the predominant source of primary energy is nuclear fission.

Figure 2 is adapted from an earlier paper[18]. It is a concept sketch of an "energy park", as several authors have discussed over the past decades. This version of the energy park concept includes all components essential to production, from fuel input to waste disposal. These components may of course, be either dispersed or concentrated. It is useful to think of them as being co-located on an "energy island", either figurative or literal. An actual island might be preferred if security and safeguards are assumed to be dominant factors in this postulated future scenario.

Figure 2 can be considered as a "target scenario"; that is, a future energy system toward which we could now aim, while recognizing that its actuality will be achieved only after several steps and stages collectively requiring several decades for implementation. The system includes fuel recycle facilities such as electrochemical reprocessing[19] or direct use of PWR fuel in CANDU (DUPIC)[21].

An energy park such as this brings with it several advantages. First it is large, so that costs of perimeter security are distributed over a number of profit centers. In addition, this large scale permits the establishment of a large staff with diverse technical skills, and a revenue base capable of supporting effective waste management systems such as zeolite trapping of radioactive noble gases. Energy from such a facility may be distributed by electrical Plant commitment strategies power lines, via tankers in the case of synthetic fuel production, or in the form of solid products such as industrial chemicals or fertilizer.

Given the high probability of ongoing supply crises in world oil and gas supply during the next couple of decades it is obvious that the only nuclear technologies ready for immediate deployment in large numbers are the pressurized water reactor (PWR), the boiling water reactor (BWR), and the pressurized heavy water reactor (PHWR). All of these reactor types produce electricity at mutually competitive prices. Further, if the authorities that must buy these power plants are conservative in their choice of appropriate technology, these plants are likely to be the same or very similar to plants operating today. As decades pass, new improved designs based on similar technologies will be chosen more frequently as their advantages come to be more strongly assured.

Recognizing that hundreds of thermal reactor plants will be operating before a significant shift toward fast-reactor powered plants comes onto the market, it may be possible to choose some variant of thermal reactor that would make the later transition easier. From the point of view of fuel cycle sustainability, the most important thermal-reactor characteristic is the amount of electricity that can be produced per unit of natural uranium required to supply fuel to the plant. By this measure, the PHWR is clearly superior.

Table I shows the energy produced per Megagram of mined uranium[18]. It shows that a fleet of PHWR reactors can produce 30-60% more electricity than can the same number of PWRs, from a given amount of mined uranium. Fuel discharged from a once-through cycle in a PHWR can be sent to a reprocessing plant to extract uranium 238 as well as some high-absorption fission products and produce fresh, recycled fuel

Table I – Energy Output per Megagram of Uranium Mined

	MWy(e)/Mg
Enriched U in PWR, BWR	4.61
Pu Recycle in PWR, BWR	5.41
DUPIC (PWR-CANDU)	6.37
Natural U in CANDU	6.37
1.2% Enriched U in CANDU	8.77

Another advantage of the PHWR is illustrated by considering a simple equilibrium steady-state ratio of thermal reactors to fast reactors in a combined system where fast reactors provide fissile isotopes to thermal reactors. Wade10 shows that this ratio is given by the equation

Number of thermal units/Number of fast units § (BR-1)/(1-CR)

The approximate values of conversion ratio (CR) and breeding ratio (BR) are: FBR = 1.4, PWR, BWR = 0.6, PHWR = 0.8, PHWR(Th) = 0.95. **Table II** lists the consequent ratio of thermal to fast reactor plants for each thermal reactor system.

Table II – Equilibrium Ratio of Thermal to Fast Reactors – Equal Energy Output

Reactor Type	Thermal/Fast Ratio
PWR, BWR	1.0
PHWR	2.0
PHWR (Th)*	5.0

*Seed-blanket fuelling with Pu-U driver fuel and Thoria blanket fuel.

When the first fast reactor begins operation the actual ratio will be much larger than this equilibrium value. As more fast reactors are started up the actual ratio will decrease with time, toward this equilibrium. New fast reactors will be fuelled from processed PWR, BWR and PHWR materials along with excess plutonium recovered from operating metal-fuelled fast reactors via electrochemical (pyrometallurgical) processing[19].

Success of the PHWR (Th) system depends entirely on the presumed capability for reprocessing discharged Th-U233 fuel and utilizing the bred uranium-233 in fast reactors. It must be recognized, however, that the achievable maximum breeding ratio with Th-U fuel in a fast reactor is somewhat lower than is achievable in a uranium-plutonium cycle. For simplicity, for this discussion we can lump uranium and thorium together as fuels, because in our integrated system all isotopes of the thorium and uranium series will be totally consumed at some step in the cycle.

A serious restriction on the growth rate of the integrated nuclear generating system arises from the shortest-achievable value of compound doubling time of FBR reactors – which is about ten years. This figure sets an upper limit (about 5 percent per year) on the rate of increase of fast-reactor-powered nuclear stations, even if all the fuel produced is recycled into new units. Of course, if other recycled fuel is available from thermal reactors, this rate can be increased so long as such recycled materials are available. Y.I. Chang[11] gives an excellent summary of these fuel-supply limitations. Clearly, the high cost of fuel would soon limit any system using only thermal reactors because they can utilize only about one percent of the potential energy in mined uranium.

Technologies – What more is needed?

The predominant area of need for new industrial capacity relates to fuel recycle. The technology of the Integral Fast Reactor (IFR) is well established[19], and a viable commercial plant design is in hand[20]. Pyroprocessing is known to work at the bench scale but still must be demonstrated on a larger scale before qualifying fully as a commercial process.

Recycling of used fuel from thermal reactors first requires extraction of uranium 238; separation of some neutron-absorbing rare earth elements via an oxidation-reduction process known as OREOX[21] could be used to improve the recycled product. The product then consists of transuranic elements and some fission products. This mixture is excellent as a fuel for fast reactors.

In a combined fuel cycle system such as this, the last step of the cycle will be located in metal-fuelled fast reactors with integral reprocessing facilities. During this final step (which will include a few recycles within each plant's reprocessing facility), essentially 100% of the transuranic elements will undergo fission. The processing facility output will, as a result, consist almost totally of fission products – an important feature of this fuel cycle, because it reduces the necessary time of waste isolation to five hundred years or less. This eliminates the need for a special long-term waste repository – final waste disposal probably can be located directly under the energy park, in a deep borehole.

Within a static or slowly growing fleet of power plants, provided that more fast reactor units are operating than the equilibrium number indicated above, the configuration of some reactors can be adjusted to reduce the amount of plutonium produced. However, in a growing fleet with fewer than the equilibrium number of fast reactors operating, the total inventory of fissile material will decrease steadily unless more is added from an external source such as reprocessed LWR fuel or newly mined uranium. The total quantity of the first is known, and limited. The quantity of uranium available is flexible and depends on the price that buyers are willing to pay. This 'demand price' can be extremely high in an equilibrium system of thermal and fast reactors because of the enormous amount of energy that can be extracted from each unit of uranium[8].

Clearly, in a system including a supra-equilibrium number of fast reactors every fissile atom has a high value because it represents an opening toward extraction of 100% of the potential energy in mined uranium. Mining, even in very low-grade deposits, still benefits from a strong economic incentive. Uranium enrichment may be required in times of rapid energy demand growth; even in that situation uranium tails may still have positive economic value because of their eventual application as blanket materials in fast reactors.

In summary, the major new components yet to be established are:

- A large and growing fleet of fast-reactor-powered nuclear plants
- An integral pyroprocessing/fabrication plant for metallic fuel at each unit
- Reprocessing plants for recycling LWR and HWR fuels
- Fabrication plants for fuel recycled from LWR and HWR units

Means other than isotopic separation may be feasible for sustaining the fissile isotope inventory in times of rapid electricity demand growth. Accelerator-driven spallation is one such possibility[5]; a fusion-fission hybrid concept also has been proposed[22].

Power Plant Sites and Characteristics

The large scale of nuclear production facilities that may be required might influence our consideration of options. To get an impression of the scale involved, the total output of about 630 one-gigawatt-electric (GWe) nuclear units would be required to replace the daily average energy released by burning gasoline in North America today.

Today's worldwide fleet of nuclear plants comprises about 430 units that in total generate less than 400 Gwe. These plants are accommodated on more or less conventional sites.

However, if plants with a projected total capacity of 5,000-10,000 Gwe are to be installed over the next decades the choice of plant sites will become a substantial problem. Very large sites (up to ~50 Gwe each) will be preferred. These sites would be large enough to sustain a broad array of technical expertise as well as fuel cycle support and security facilities. Comprehensive security systems would be a necessary and affordable feature. Recycling, waste management and disposal systems would be included. Secondary industries such as hydrogen production and synthesis of liquid transportation fuels could be established on the same site. Distribution of energy from such sites will require a large infrastructure – not unlike that surrounding large oil and gas production centers such as those in the Persian Gulf. Manufacture of satellite power systems[10, 10a] also may be undertaken. These satellite systems can be considered as a further means of distributing potential nuclear energy from these large central sites.

Site Facilities

An energy center should be built step by step, according to a broad but adaptable overall plan. The Bruce site on Lake Huron provides a good example of how such a complex might begin[23]. The site now includes about 7 Gwe of generation plus a number of support facilities. Some years ago, a conceptual plan[24] was put forward for a multi-stage energy cascade system adjacent to the site. On-site used fuel storage facilities are already in place. Heavy water production plants that were a feature of the site in earlier days are shut down.

The next step of site development could be addition of more generation capacity; if this step is taken in the near future a good choice will be CANDU reactor units, either of the type now operating or the new ACR type. Later on, integral fast reactors might be added as a first move toward a system with a closed fuel cycle. These reactors could utilize the used CANDU fuel now stored on site, given the addition of a processing plant. (There is already sufficient used fuel on site to power an integrated generation complex of ~1 5 Gwe for several hundred years.) A U238 extraction plant could upgrade this fuel and supply the first charge to each fast reactor as well as recycling mixed-oxide fuel to onsite CANDU units. Depending on the rate of capacity buildup it may be necessary to supply a limited amount of enriched uranium or separated plutonium to the site from external sources.

Depending on circumstances in the external market, management of a mature site such as this might choose to install a number of fast reactors above its equilibrium level, and sell plutonium-bearing fuel to other similar sites still under development under strict international control. The core and radial blanket configuration of each fast reactor can be adjusted to regulate amount of excess plutonium produced on the site.

Fuel Supplies

Fuel requirements are very small at an integrated fast-thermal reactor site. Basically, the amount of fresh uranium needed to sustain a metal-fuelled fast reactor using integral pyroprocessing, located on an ocean site, will be less than the amount of uranium dissolved in the seawater required to cool its turbine condenser (seawater has a dissolved uranium concentration of 3 parts per billion.) In other words, only about 1/100th of the amount of fresh uranium now required per operating megawatt of capacity will be sufficient to sustain generation. The Bruce Energy Centre is a fresh water site; this illustration simply indicates the very small quantity of uranium needed to sustain such an integrated system.

World Nuclear System by 2100

It is possible to imagine a world energy supply system operating in about 100 years. That system could consist of 10,000

Gwe of generation and associated peripheral systems, located on 100-200 sites worldwide. Some of these sites might be dedicated to production of synthetic petroleum liquid and gas as well as a wide range of other industrial processes. At the low-temperature end of production cascades one might find food-related installations such as fertilizer production and fish farming. This network of large energy parks might be interspersed with smaller, independent installations using sealed "nuclear battery" power systems[10]. Reference 10a outlines an extension of this concept.

There is enough uranium available for human use so that this large-scale world energy supply can be sustained for at least several thousand years[8].

Conclusions

This "Blue Sky' concept paper shows that a sustainable nuclear system can be built up, step by step, from components and systems already proven and available today, and augmented by simple extensions of proven concepts – all well within the realm of known technology. Further work is required to guide the selection of reactor types and fuel cycle facilities during development of energy parks. Several prototype facilities must be established before commercial viability can be proven.

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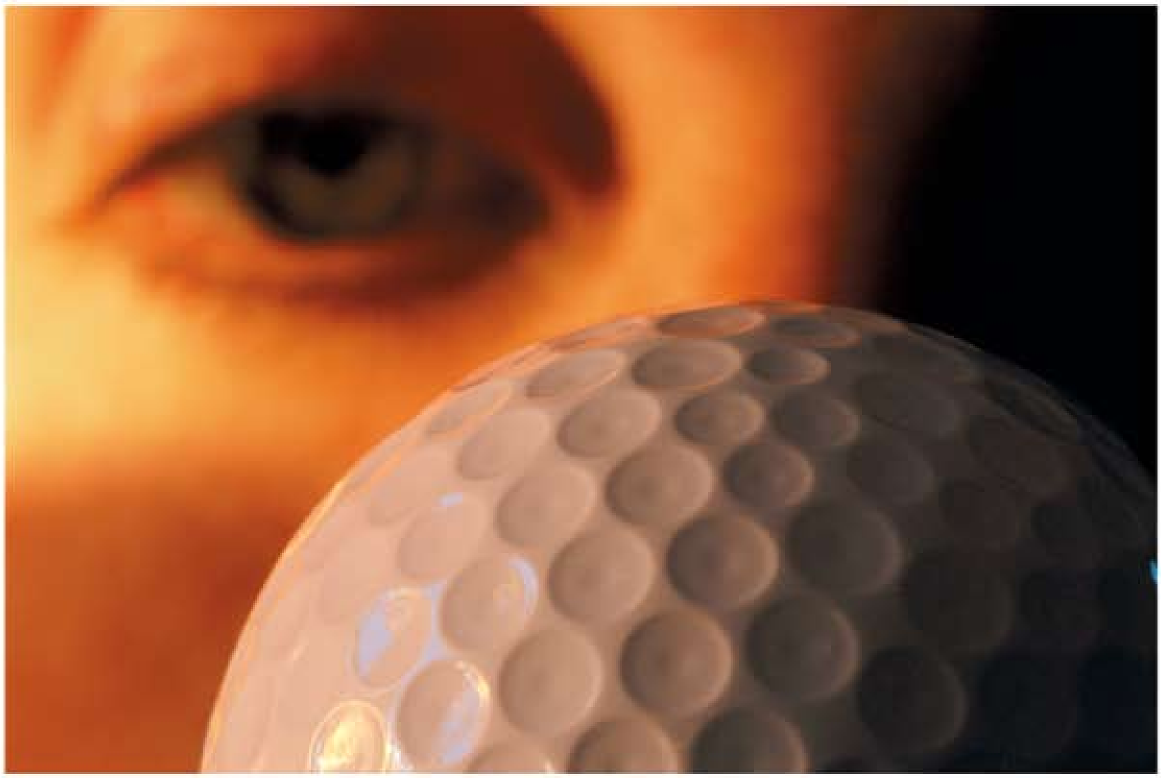

Pre-Licensing of The Advanced CANDU Reactor

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Ed. Note: The following paper is an updated version of one, under the same title, presented at the 27th Annual CNS Conference in Toronto, Ontario, June 2006.

1. Introduction

Atomic Energy of Canada Limited (AECL) developed the Advanced CANDU Reactor™-700[3] (ACR-700™) as an evolutionary advancement of the current CANDU 6®[4] reactor. As further advancement of the ACR design, AECL is currently developing the ACR-1000™[1] for the Canadian and international market. The ACR-1000 is aimed at producing electrical power for a capital cost and a unit-energy cost significantly less than that of the current generation of operating nuclear plants, while achieving shorter construction schedule, high plant capacity factor, improved operations and maintenance, increased operating life, and enhanced safety features. The reference ACR-1000 plant design is based on an integrated two-unit plant, using enriched fuel and light-water coolant, with each unit having a nominal gross electrical output of 1165 MWe.

The ACR-1000 design has evolved from AECL's in-depth knowledge of CANDU systems, components, and materials, as well as the experience and feedback received from owners and operators of CANDU plants. The ACR design retains the proven strengths and features of CANDU reactors, while incorporating innovations and state-of-the-art technology. It also features major improvements in economics, inherent safety characteristics, and performance, while retaining the proven benefits of the CANDU family of nuclear power plants.

The CANDU system is ideally suited to this evolutionary approach since the modular fuel channel reactor design can be modified, through a series of incremental changes in the reactor core design, to increase the power output and improve the overall safety, economics, and performance.

The safety enhancements made in ACR-1000 encompass improved safety margins, performance and reliability of safety related systems. In particular, the use of the CANFLEX®[5]-ACR fuel bundle, with lower linear rating and higher critical heat flux, provides increased operating and safety margins. Safety features draw from those of the existing CANDU plants (e.g., the two independent shutdown systems), and other features are added to strengthen the safety of the plant (e.g., a passive gravitydriven water supply from a reserve water system to provide various back-up heat sinks). These and other safety improvements serve to reduce the licensing risk of the design.

2. ACR-1000 Licensing Objective

The AECL licensing objective for the ACR-1000 is to support the overall objective of a successful deployment in Ontario. To achieve this, a pre-licensing review is being undertaken with the Canadian Nuclear Safety Commission (CNSC). AECL's goal of the pre-licensing review is aimed at obtaining a positive licensability statement for the ACR1000, thereby reducing the licensing risk at the time of project commitment with a utility in Ontario.

AECL and CNSC signed a Memorandum of Understanding (MOU) in November 2005, which defined four phases of the ACR pre-licensing review.

In Phase 1 (September 2003 to September 2004) CNSC performed a licensability review of the ACR-700, and focused on the design process, methodology, design concepts and R&D. CNSC staff reviewed about 100 reports, and submitted to AECL questions and comments. In Phase 2 (September 2004 to August 2005) AECL provided responses and additional information to CNSC on their comments and questions in Phase 1. Phase 3 is the Transition Phase (September 2005 to May 2006), which occurred during the transition from the ACR-700 to the ACR-1000 design. Phase 3 focused on review of generic aspects of the ACR design, the Safety Analysis methodology, and on review of the draft CNSC design requirements for new reactor designs. In Phase 4 (June 2006 to June 2009) AECL is preparing and submitting to CNSC the documents that constitute the Preliminary Safety Case Package for the ACR-1000, and CNSC will issue the Licensability Assessment Report.

AECL's primary objectives for the pre-licensing are to:

1. Identify any potential regulatory issues early in the design, so there is time to address them before project commitment;
2. Provide a reasonable assurance to a utility that the licensing risk to cost and schedule of the project from licensing is acceptable before a project is committed; and
3. Use the results of pre-licensing in the project review, so the latter takes less time.

3. Licensing Milestones

In order to reach the goal in support of a successful deployment of the ACR-1000 in Ontario, a number of specific major milestones have to be accomplished. These milestones are:

1. Obtain from CNSC a licensability statement. The current

1 Atomic Energy of Canada Limited, Mississauga, Ontario, Canada L5K 1B2

2 Candesco Co., Toronto, Ontario

3 ACR-700™ and ACR-1000™ (Advanced CANDU Reactor™) are trademarks of Atomic Energy Canada Limited (AECL).

4 CANDU® (CANada Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Limited (AECL).

5 CANFLEX® is a registered trademark of AECL and the Korea Atomic Energy Research Institute (KAERI).

ACR schedule date for CNSC to issue a statement of licensability is June 2009;

2. Obtain a Site Preparation Licence (Permit). A site preparation licence granted by the CNSC is a prerequisite to the start of major equipment procurement, and to the start of site preparation. It is issued after a positive decision is obtained regarding the Environmental Assessment.
3. Obtain a Construction Licence (Permit);
4. Obtain an Operating Licence.

4. Licensing Objectives

In order to meet each of the licensing milestones, the following high-level objectives have to be accomplished.

4.1 Submit the Preliminary Safety Case Package

AECL will issue a complete and timely Preliminary Safety Case Package (PSCP) to the CNSC. The PSCP consists of a series of ACR-1000 documents that are scheduled to be issued in the period from January 2006 to March 2008.

Note that the submittal of the PSCP to the CNSC is a pre-licensing objective and occurs before the start of an ACR project in Ontario.

4.2 Minister's Environmental Assessment Decision

The critical path objective in obtaining the site preparation licence is to have a positive Minister's Environmental Assessment (EA) decision. A pre-requisite to this objective is for AECL (and partners), or a utility proponent, to initiate and complete the EA program task. Note that the EA process for a new nuclear power plant build assumes a Panel review [1]. The EA requires preparation and submission of design documentation of good quality and adequate detail to the members of the EA Panel for the assessment of the impact on the environment.

4.3 Issue Preliminary Safety Analysis Report

The Preliminary Safety Analysis Report (PSAR) is one of the requirements for a construction licence.

4.4 Issue Final Safety Analysis Report

The Final Safety Analysis Report (FSAR) is one of the requirements for an operating licence.

5. Major Licensing Tasks And Activities

The major tasks associated with the PSCP are listed below.

5.1 Memorandum of Understanding and Continuous Engagement of CNSC

AECL signed the Memorandum of Understanding (MOU) with the CNSC in November 2005. The MOU lists the technical scope and work phases, and the pre-licensing objectives. A support document (ACR Pre-licensing Technical Review Scope) lists all the deliverables that AECL has committed to submit to CNSC, and CNSC will review as part of the ACR pre-licensing.

5.2 Review and Trial Use of CNSC's Design Requirements Document

In March 2005, the CNSC issued for trial use the pre-consultation draft "Requirements for Design of Nuclear Power Plants" (DRD). AECL reviewed the draft document and provided CNSC with a list of questions and 19 position papers on topics that required further clarification. CNSC has provided feedback on AECL's position papers and questions in April 2006.

The DRD will be revised internally by the CNSC and be re-issued for public consultation as a regulatory document. The information contained to date does not represent a final regulatory position on the matter.

During the ACR-1000 Basic Engineering Program (BEP), discussions with CNSC staff will be conducted at the detailed design level to ensure good understanding of the new requirements, and ensure compliance of the ACR-1000 design with the DRD requirements or their intent.

5.3 Address and Disposition CNSC's Comments

CNSC issued a number of comment packages during the first phases of the pre-licensing review. AECL responded to those comments. AECL will also be addressing during the BEP any further comments that will be received to ensure the ACR-1000 design meets CNSC requirements.

6. Licensing Risk And Risk Mitigation

Certain risks can be identified and associated with the licensing milestones and further down to licensing objectives, tasks and activities. The main factor regarding the licensing risk is the uncertainty related to the formal licensing process of the ACR. Most high-level licensing risks are associated with the developments regarding the regulatory process and updated requirements. The regulatory framework in Canada is currently in a period of change. Specifically, changes or updates in the CNSC's licensing process in Canada have been covered in a document recently issued by CNSC [1]. For example, the ACR-1000 could be the first new nuclear power plant to undergo an Environmental Assessment under the CEAA. Changes in specific regulatory requirements (e.g., DRD) are taking place concurrently, as well.

Risk mitigation activities are on-going to reduce the uncertainty associated with the changing regulatory framework, for example, AECL will start the preparatory work for an EA as early as possible and also started to engage CNSC in discussions regarding implementation of the DRD requirements for ACR-1000.

7. ACR Licensing Basis

The ACR-1000 regulatory and licensing approach is to ensure adherence to Canadian and applicable international requirements, codes and standards by providing:

- A plant design that complies with Canadian licensing requirements;
- A plant design that can be readily adapted to meet applicable international requirements without major changes;
- A Quality Assurance (QA) program which satisfies the requirements of the Canadian and applicable international QA codes and standards, as specified by the regulators;
- A plant design that takes into consideration the installation of safeguard and sabotage preventive systems to meet Canadian and international requirements, and to satisfy the safeguards requirements of the International Atomic Energy Agency (IAEA).

The ACR-1000 design will comply with the nuclear regulatory policies and requirements within Canada and will consider regulatory policies in other potential market countries that may have an impact on the design.

7.1 Regulatory Compliance and Licensing

The licensing process for nuclear reactors in Canada is the means by which the CNSC gains assurance that a nuclear facility will be sited, designed, constructed, commissioned, operated and decommissioned in compliance with safety criteria and requirements established by the CNSC based on the Canadian Nuclear Safety and Control Act.

To ensure ACR-1000 is licensable in Canada, the following requirements and activities are set:

- The ACR1000 plant will be designed to fulfill all applicable Canadian regulatory requirements including taking into account the proposed CNSC Requirements for Design of Nuclear Power Plants;
- The design will comply with all applicable Canadian codes and standards;
- Design solutions will be provided for Generic Action Items (GAIs). Direct design solutions for GAIs will be implemented and, for issues where direct design solutions may not be feasible, AECL will provide assurance that the major contributors to risk and the major sources of uncertainty associated with the issue have been identified and addressed.

A pre-licensing review of the ACR is conducted with the CNSC during the Basic Engineering Program (BEP) phase as previously noted. Issues raised by the CNSC during the review will be addressed by design or provision of design support information such that no fundamental barriers exist.

To ensure the design is licensable internationally the following licensability requirement is set:

- Regulatory policies and requirements from other target-market countries and the IAEA will be reviewed, and where applicable, the ACR1000 design will either comply with these requirements, or where this would adversely impact meeting one or more of the other objectives for the Canadian market, the design will be made readily adaptable to meet the regulatory requirements of other jurisdictions and the IAEA.

In this respect the IAEA Safety Standards Series Requirements Document NS-R-1 [2] will be used in the ACR-1000 design.

8. ACR Pre-application Review In The US

Between mid-2002 and 2005 AECL Technologies (AECLT, a wholly owned US subsidiary of Atomic Energy of Canada Limited) was the proponent of preapplication review of the ACR700 design with the US Nuclear Regulatory Commission (NRC) in the United States.

Under the preapplication review, 13 focus topics were established for NRC review and about 25 technical meetings were held. Approximately 35 formal documents and more than 300 additional supporting documents were submitted during this time for the NRC review.

The results of the NRC staff preapplication review have been documented in a PreApplication Safety Assessment Report (PASAR) [3] that was issued in October 2004. The review conclusions by the USNRC staff as documented in the PASAR report are as follows:

"On the basis of its review of the materials submitted by AECL, including responses to requests for additional information, the staff concludes that the applicant will need to pursue a number of technical issues in more detail to reach satisfactory conclusions for design certification. The policy, regulatory, and technical issues involved are complex. Notwithstanding, based on the information provided, the staff believes at this time that AECL will ultimately be able to satisfactorily address these policy, regulatory, and technical issues during the design certification review."

9. ACR Preapplication Review In China

Pursuant to the bilateral agreement between AECL and the Chinese nuclear regulator, National Nuclear Safety Administration (NNSA) and its technical supporting organization, Nuclear Safety Center (NSC), the NNSA/NSC is reviewing the ACR1000 in the following seven focus areas:

1. ACR Licensing Basis;
2. Safety Important Structures and Components;
3. Reactor Core;
4. Safety Important Fluid Systems (Including Primary Loop Systems, Safety Systems, and Radioactive Waste Management Systems, etc.);
5. Instrumentation and Control as well as Electrical Power Systems;
6. Design Basis Accidents and Severe Accidents; and
7. Probabilistic Safety Assessment.

The main objective of the preapplication review by NNSA/NSC is to review ACR's compliance with the Chinese regulatory requirements.

The scope of the pre-application review by the NSC staff includes the following:

- Review key design requirements and methodology documents of ACR to identify potential design and analysis areas in which compliance with Chinese regulations is not readily apparent, and
- Perform a follow-up review of selected issues identified during Qinshan III licensing process.

The NSC review is focused on the following ACR documentation: Design Requirements, Methodologies, Safety Basis, Criteria, Tools, Assumptions, R&D plan, and Verification plan.

To facilitate the review, the NSC is sending its experts to CNSC for in-depth familiarization with the ACR design and participation in the ACR technical review being performed by the CNSC. The ACR preapplication review will also benefit from past experience in successfully licensing CANDU 6 reactors in China.

10. Conclusions

The Canadian Nuclear Safety Commission is currently performing a pre-licensing review of the Advanced CANDU Reactor design to assess its licensability in Canada. The first part of the prelicensing review was focused on the ACR-700 design. The second phase of the pre-licensing review is currently focusing on the ACR-1000 design. The licensability review will not constitute a licence, but in AECL's view will provide a reasonable assurance to a utility that there will be no fundamental barriers to licensing the ACR-1000 in Canada.

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An artists depiction of a two-unit ACR nuclear station

Regulatory Approach for Life Extension of Nuclear Power Plants in Canada

by D. G. Miller, I. M. Grant, K. Lafreniere and P. Webster[1]

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Abstract

Canadian nuclear utilities have recently completed the Pickering A Units 1 and 4 and Bruce A Units 3 and 4 return to service projects. Other similar projects which have been announced include New Brunswick Power Nuclear's decision to proceed with the Point Lepreau life extension, and Bruce Power's plans to go ahead with the life extension of Bruce A Units 1 and 2.

The projects to date have been carried out within the existing Canadian nuclear regulatory framework and the operating licenses issued by the Commission for each facility. Key regulatory goals have been to:

- ensure adequacy of the scope of refurbishment and safety upgrades proposed by the licensee; and
- verify the proper execution of that work by the licensee, prior to return of the unit to service.

This paper describes elements of the CNSC requirements and regulatory oversight plans to achieve these goals. Work is ongoing to develop formal regulatory guidance.

Introduction

In recent years, Canadian nuclear utilities have completed several refurbishment projects, notably the return to service of the Pickering A Units 1 and 4 and Bruce A Units 3 and 4. New Brunswick Power Nuclear Corporation recently announced a decision to proceed with the Point Lepreau life extension project with on-site refurbishment planned to start in 2008. Bruce Power has announced plans for the life extension of Units 1 and 2. Projects for other facilities also are under consideration.

The projects to date have been carried out within the existing Canadian nuclear regulatory framework and the operating licenses issued by the Commission for each facility In Canada, the operating life of a plant has not been defined in regulation. Plants are licensed to operate provided that the licensee can demonstrate that the facility will not pose an unreasonable risk to health, safety, security and the environment and will conform with Canada's international obligations.

Renewal of the operating licence at intervals, currently, every five years for power reactors, affords periodic review and updating of the design and the basis for safe operation of the plant. Nevertheless, life extension projects represent by their nature a commitment by the operator to long-term, continued operation of the facility. The CNSC considers it to be in the public interest that before any such project proceeds there is assurance that the facility will meet appropriate standards for safe and secure operation over its planned life, and that the refurbishment work is done properly.

Accordingly, key regulatory goals for life extension projects are:

- ensure adequacy of the scope of refurbishment and safety upgrades proposed by the licensee; and
- verify the proper execution of that work by the licensee, prior to return of the unit to service.

The regulatory requirements that have been established for such projects, and elements of the regulatory oversight activities to achieve these goals are outlined below.

Establishing The Life Extension Workscope

The following steps have been required of licensees in establishing the scope of work:

- perform an Environmental Assessment (EA);
- carry out an Integrated Safety Review (ISR); and
- based on the results of the EA and ISR, develop an integrated implementation plan for the
- necessary refurbishment, safety upgrades and compensatory measures to ensure the facility will pose no unreasonable risk to health, safety, security and the environment and will conform with Canada's international obligations over the proposed life.

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Environmental Assessment

Pursuant to the Canadian Environmental Assessment Act (CEAA), an EA for the project needs to be completed with a positive decision before any regulatory approvals or licensing actions are given that enable the project to proceed.

A screening EA has been required under the CEAA regulations for past and present life extension projects. However, a new EA may not be needed at the time of the life extension, if the requirements of the CEAA Exclusion List Regulations are met.

In establishing the scope of a project for a screening environmental assessment under the CEAA, the physical works that are involved in the proposal and any specific undertaking that will be carried out in relation to those physical works must be determined.

The scope of a screening environmental assessment under the CEAA includes all the factors identified in paragraphs 16(1) (a) to (d) of the CEAA and, as provided for under paragraph 16(1) (e), any other matter that the CNSC requires to be considered. Paragraphs 16(1) (a) to (d) require that the following factors be included:

- the environmental effects of the project, including the environmental effects of malfunctions or accidents that may occur in connection with the project and any cumulative environmental effects that are likely to result from the project in combination with other projects or activities that have been or will be carried out;
- the significance of the effects identified above;
- comments from the public that are received in accordance with the CEAA and its regulations; and
- measures that are technically and economically feasible and that would mitigate any significant adverse environmental effects of the project.

The EA typically includes the following [1]:

- spatial and temporal boundaries of the assessment;
- description of the existing environment;
- assessment and mitigation of environmental effects including a description of assessment methodology, the effects of the phase of project (e.g. construction), and the effects of normal operations, malfunctions and accidents, and natural hazards.
- cumulative environmental effects;
- significance of residual effects; and
- stakeholder consultation.

Integrated Safety Review

The Integrated Safety Review (ISR) is an assessment of the plant design and operation performed in accordance with the IAEA Periodic Safety Review (PSR) guidance [2]. The ISR is a comprehensive self-assessment carried out by the licensee. It is considered an effective way to obtain an overall view of actual plant safety, to determine reasonable and practical modifications that should be made in order to maintain a high level of safety, and to improve the safety of older nuclear power plants to a level approaching that of modern plants.

Table 1: IAEA Periodic Safety Review Safety Factors

Plant	Plant Design Actual Condition of Systems, Structures and Components Equipment Qualification Ageing
Safety Analysis	Deterministic Safety Analysis Probabilistic Safety Analysis Hazard Analysis
Performance and Feedback of Experience	Safety Performance Use of Experience from other Plants and Research Findings
Management	Organization and Administration Procedures Human Factors Emergency Planning
Environment	Radiological Impact on the Environment

The ISR involves a comparison of the actual state of the plant and plant performance with modern high-level safety goals and requirements, taking into account operating experience in Canada and around the world, new knowledge from research and development activities, and advances in technology.

In the IAEA PSR document, there are fourteen safety factors organized into five subject areas to facilitate the review (Table 1). In addition, there is a global assessment to integrate the results of the review of individual safety factors. Security and safeguards would also be reviewed.

Integrated Implementation Plan for Safety Improvements

The licensee assessed the results of the EA and the ISR and develop an integrated implementation plan for the necessary corrective actions, safety upgrades and compensatory measures to ensure the facility will not pose an unreasonable risk to health, safety, security and the environment and will conform with Canada's international obligations over the proposed life.

All generic action items and station-specific actions items need to be reviewed and each need to be resolved to the extent practical.

As part of the ISR, licensees are expected to compare the facility with modern safety standards for design and operation and to propose measures to address any shortfalls. Licensees may elect to submit cost-benefit information in support of their proposed workscope [3].

In assessing the adequacy of the life extension workscope proposed by the licensee, CNSC staff reviews the Environmental Assessment Study Report and the Integrated Safety Review report, and takes into consideration information gathered through its own regulatory oversight activities.

The CNSC assesses the proposed workscope against:

- NSCA, regulations, standards, guides
- Information gathered on station-specific performance though our regulatory oversight program
- deterministic safety criteria;
- operating experience (station-specific, CANDU-specific, world-wide);
- expert knowledge;
- insights from probabilistic safety analysis;
- PSR review criteria; and
- modern international standards where applicable.

The CNSC notifies the licensee of its assessment of the proposed workscope, either accepting it or requiring changes. Subsequently the licensee proceeds with execution of life extension activities.

Once the licensee has notified the CNSC of its intent to proceed with life extension, pre-requisites for start-up following the life extension work are identified. These pre-requisites are introduced via incorporation of specific conditions in the operating licence. Approvals to carry out specific activities may also be needed once life extensions activities have commenced in the field.

Verification Of Execution Of Life Extension Activities

Once life extension activities are underway, the licensee needs to have acceptable programs for the control of all life extension activities, and to support normal operation, as required by the operating licence.

Requirements for project execution include acceptable programs in the following areas:

- Quality Management;
- Configuration Management;
- Management Activities to Control Outage;
- Control of Contractors;
- Radiation Protection;
- Design/Engineering Change;
- Commissioning;
- Personnel Qualification and Training;
- Conventional Health & Safety;
- Waste Management;
- Emergency Preparedness;
- Environmental Protection;
- Security; and
- Safeguards.

Regulatory verification of project execution includes assessment of engineering change submissions, and inspections of licensee procurement, construction and commissioning activities. Engineering change, procurement, construction and commissioning are to be performed in accordance with CNSC requirements and appropriate industry standards. The CNSC also assesses the adequacy of updates of licensee programs for the operation and maintenance of the plant. In addition, there will be verification that the programs for the control of life extension activities are adequate.

The CNSC expects the licensee to carry out a thorough commissioning plan for a life extension project. If relevant system baseline data is available from past commissioning, then it can be referenced. However, if commissioning baseline data is no longer available, it will have to be regenerated.

Commissioning is divided into three phases (Phases A to C). Phase A confirms correct installation of new equipment and confirms fitness for service of new and existing plant features through a program of individual component and integrated system testing. Phase B activities are carried out at low reactor power and focus on confirming the reactor behaviour under these conditions. Phase C focuses on demonstrating that the reactor and systems perform as expected at power levels up to full reactor power.

Following the return to full power operation, the CNSC will continue to monitor facility operation through its regulatory oversight program.

Public Hearing Process

At the hearings for renewal of the licence that will be in effect at the time of life extension activities, the licensee must show to the Commission that it is qualified and will make adequate provision for protection of health and safety in carrying out for the contemplated life extension activities. Staff will recommend license conditions that require the licensee to demonstrate completion of prerequisites, and to gain the approval of the designated officer or the Commission before the stages of return to service.

The decision regarding delegation of authority is rendered by the Commission following the process set out in the CNSC Rules of Procedure Regulations (SOR/DORS/2000-211) [4]. The Public Hearing is typically held over two days. The licensee and CNSC staff are required to submit information 30 days in advance of the Day 1 Hearing. A Day 2 Hearing is held about 60 days following the first hearing day. The public, the licensee and CNSC staff submit information 30 days prior to the Day 2 Hearing.

Summary

Canadian nuclear utilities have completed several reactor refurbishment projects and further such projects are planned.

The projects to date have been carried out within the existing Canadian nuclear regulatory framework and the operating licenses issued by the Commission for each facility. The CNSC's regulatory goals for life extension projects are:

- obtaining assurance of the adequacy of the scope of refurbishment and safety upgrade work proposed by the licensee; and
- verifying the proper execution of that work by the licensee, prior to return of the unit to service.

To achieve these goals, licensees are expected to perform an EA under the Canadian Environmental Assessment Act, to perform an ISR following the guidance in the International Atomic Energy Agency Guide on Periodic Safety Review, and to incorporate the results of the EA and the ISR into a comprehensive implementation plan for refurbishment, safety upgrades and compensatory measures.

The CNSC assesses the proposed life extension work scope, evaluates the licensee programs for the control of all life extension activities, and evaluate engineering, procurement, construction and commissioning activities carried out during the refurbishment outage.

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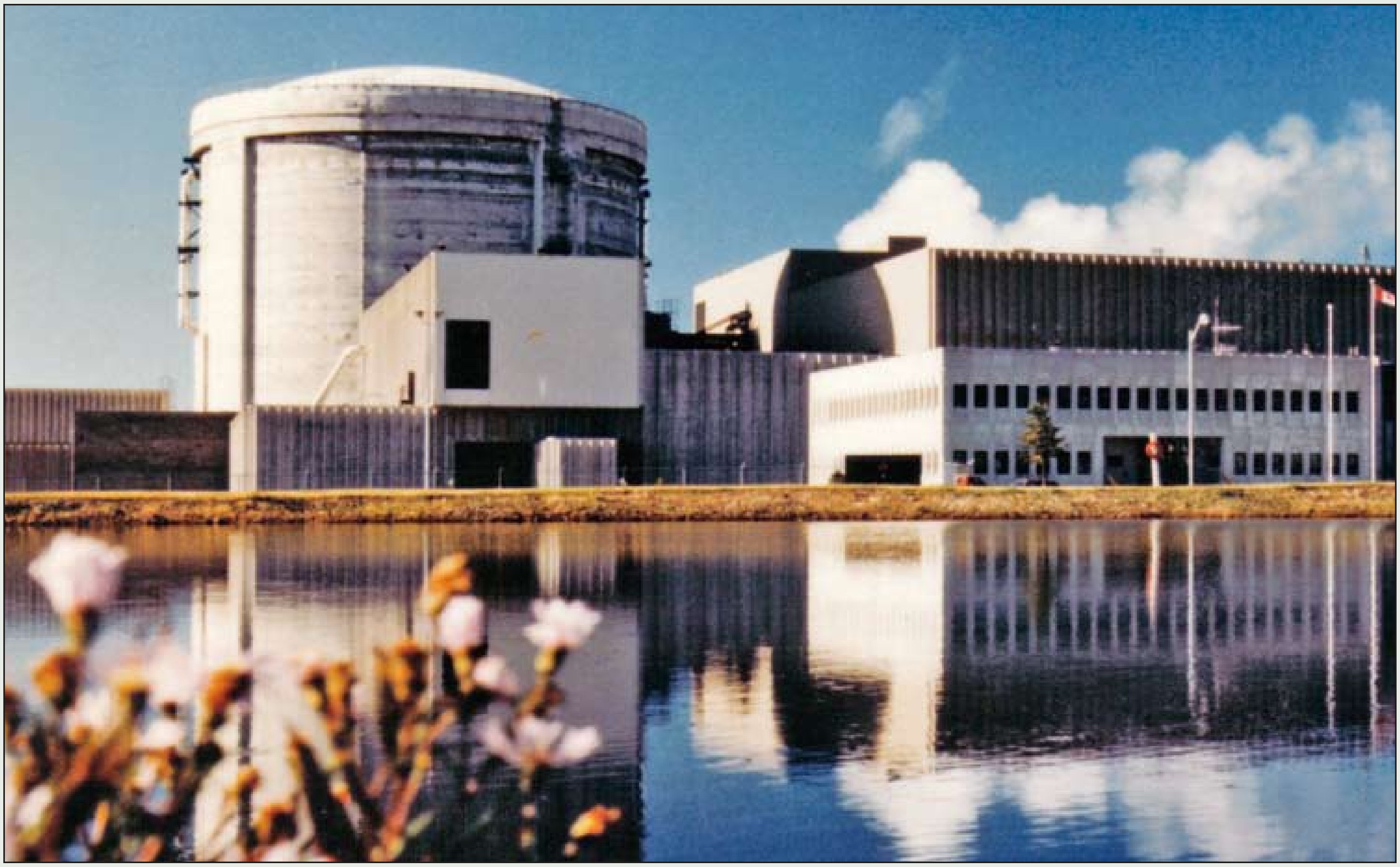

A view of the Point Lepreau nuclear gnerating station in New Brunswick which is scheduled to begin a major refurbishment in the spring of 2008.

Homogeneous Slowpoke Reactor for the Production of Radio-Isotope: A Feasibility Study

by Paul Busetta and Hugues W. Bonin[1]

Abstract

The purpose of this research is to study the feasibility of replacing the actual heterogeneous fuel core of the present SLOWPOKE-2 by a reservoir containing a homogeneous fuel for the production of Mo-99. The study looked at three items: by using the MCNP Monte Carlo reactor calculation code, develop a series of parameters required for an homogeneous fuel and evaluate the uranyl sulfate concentration of the aqueous solution fuel in order to keep a similar excess reactivity; verify if the homogeneous reactor will retain its inherent safety attributes; and with the new dimensions and geometry of the fuel core, observe whether natural convection can still effectively cool the reactor using the modeling software FEMLAB(r). It was found that it is indeed feasible to modify the SLOWPOKE-2 reactor for a homogeneous reactor using a solution of uranyl sulfate and water.

Molybdenum 99 Production Using a Homogeneous Reactor

Molybdenum 99 (Mo-99) is used to produce Technetium 99m (Tc-99m), the most widely used radioisotope in nuclear medicine. Its short half-life of six hours and its emitted gamma energy of 140 keV make it an ideal imaging agent. Mo-99 is obtained largely from the fission of U-235. Targets of U-235 are exposed to a neutron flux in a nuclear reactor. The target is an uranium/aluminium alloy, in which highly enriched uranium (HEU) or low enriched uranium (LEU) is used. The irradiated targets are then dissolved in an alkaline or acidic solution and the fission product of the U-235, Mo-99, is extracted by solvent extraction from the solution of targets and solvent by chemical treatment steps such as passing through several absorber columns and ion-exchangers. This method creates important amount of radioactive waste from the U-235 targets. Table 1 presents an overview of all the liquid produced for the production of 3000 Ci of ^{99}Mo in the Netherlands. Even though several methods are used by other manufacturers, this method still gives a good approximation of the waste produce[1].

Research has been conducted to reduce, handle, and treat the waste created by the production of Mo-99. In 1992, Russell M. Ball introduced the use of a homogeneous nuclear reactor for the production of Mo-99 with the following advantages[2]:

- No requirements to produce and transport targets;
- Full utilization of fission product Mo-99. In target irradiation, all the fission products (and the resulting production of Mo-99) in the reactor used to produce the neutrons that irradiate the target are wasted. The Mo-99 remains in the solid reactor fuel;

Table 1: Characteristics of Liquid Waste per Hot Cell after Production of 3000 Ci 99Mo. (Ref 1.)

Liquid From	Volume (l)	Content (g l_{-1})	Activity (MBq l_{-1})
Cell 1 Intermediate level waste (ILW)	8,2	NaOH 240 Al 20 U 0.005	^{89}Sr 740 ^{90}Sr 630 ^{137}Cs 6400
Cell 2 ILW	10.5	$NaNO_3$ 102 NaOH 29.6	^{103}Ru 500 ^{106}Ru 46 ^{125}Sb 4.6
Cell 3 Low Level Waste (LLW)	7.3	Na_2SO_4 115 NaI 0.06 Na_2SO_3 121 NaOH 16 NaSCN 4	^{103}Ru 5 ^{106}Ru 0.46 ^{125}Sb 0.046
Cells 4 and 5	4.7	NaOH 12 NaNO3 17	^{103}Ru 0.040 ^{106}Ru 0.0037

1 Masters student and Professor, respectively, Royal Military College, Kingston, Ontario

- Discarded fission products are 1/100th of the total fission products produced in the target method for a given quantity of Mo-99;
- The uranium consumption and the heat production are 1/100th of that produced in the target method;
- The extraction process is simplified with no subsequent uranium dissolution required.

In 1998, the Kurchatov Institute designed a Mo-99 extraction procedure using a homogeneous reactor. The irradiated fuel solution is then passed through a proprietary sorbent, which separates the Mo-99 from the rest of the solution, the remaining solution being sent back to the reactor. The Mo-99 is then separated from the sorbent using an acid solution.

Homogeneous Nuclear Reactor

Homogeneous nuclear reactors are reactors for which the fuel, the coolant and the moderator are distributed uniformly and homogeneously throughout the core. The fuel and moderator could be solid or liquid (the coolant must be a fluid (liquid or gas)). The type of homogeneous reactor of interest for this study is the aqueous homogeneous reactor. The aqueous homogeneous reactor uses the fuel in an ionic state in an aqueous solvent that is used as coolant as well as and moderator. In contrast, in the heterogeneous nuclear reactor, the fuel is kept physically separated from the moderator (and coolant) by means of cladding (or sheathing). The following is a list of all the advantages and disadvantages of the homogeneous reactor in the liquid aqueous form.

Advantages of homogeneous nuclear reactors.

1. Reactor's high specific power. Because the coolant and fuel are part of the same solution, there are no heat transfer barriers and the power density is only limited by the temperature rise of the fuel itself and the heat removal capacity of the system.
2. High burn-up of fuel. the aqueous homogeneous reactor has the possibility of removing the so-called "poisons fission products" and adding fresh fuel on a continuous basis, therefore permitting very high burn-up and very efficient use of the nuclear fuel.
3. Simple fuel preparation and processing. There is no need of complex and expensive fuel element fabrication, resulting in lower costs of fuel preparation for the homogeneous reactor.
4. Loading and discharging of fuel can be done on-line, thanks to a extensive fuel handling facility, which constitutes yet another advantage.
5. Homogeneous reactors allow high neutron economy in minimizing the neutron absorption by avoiding the need for cladding and structural material within the reactor core.
6. Simple control systems are possible with homogeneous reactors. Increasing the core temperature leads to a decrease of the homogeneous fuel mixture density, thus creating a strong negative temperature coefficient of reactivity which makes the system self - stabilizing, thus eliminating the need for complicated safety systems.[3]

Disadvantages

1. Corrosion or erosion of equipment: The circulation of the homogeneous fuel mixture at high flow rates creates corrosion and erosion problems in the reactor and circulating equipment.
2. The external circulation of the fuel solution: In order to remove the fission products and isotopes from the fuel and to condition the fuel outside the reactor core, the highly radioactive mixture is circulated outside the reactor core.
3. The inventory of the fuel: It needs to be higher than the content of the volume of the core. This increase of fuel inventory of fuel and the need to handle relatively large quantities of highly radioactive fuel mixture result in increased induced activity within in the external equipment and in additional shielding requirements and maintenance problems.
4 Restriction in the concentration of uranium in the fuel solution: In aqueous homogeneous reactors, the concentration of uranium is limited by solubility and the corrosion effects of high concentrated solutions. Figure 1, which presents the phase diagram for the system $UO_2SO_{4-}H_2O$, displays the level of solubility of $UO_2SO_{4-}H_2O$ in moles per kg of water at different temperatures. As observed in Figure 1, the fuel solution becomes saturated at 4.3 moles of $UO_2SO_{4-}H_2O$ per kg of water at a temperature of 50°C.
5. The last disadvantage of the homogeneous reactor is the production of explosive gases. Radiation induces the decomposition of the moderator (water), which can produce an explosive mixture of hydrogen and oxygen within the reactor system. This hazard means that special precautionary design measures must be taken such the use of catalytic recombiners.[3]

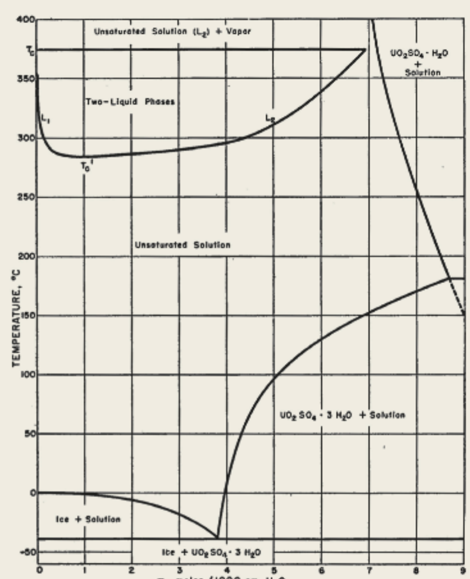

Figure 1: Phase Diagram for the System UO_2SO_4 –H_2O [Ref 3]

Even though the list of advantages and disadvantages applies primarily to power generation reactors that require higher neutron fluxes, temperatures, pressures and coolant flow rates, it is still valid for smaller reactors albeit to a lesser extent, and the disadvantages may not represent obstacles important enough to preclude the design of a small homogeneous reactor such as the one investigated in the present work

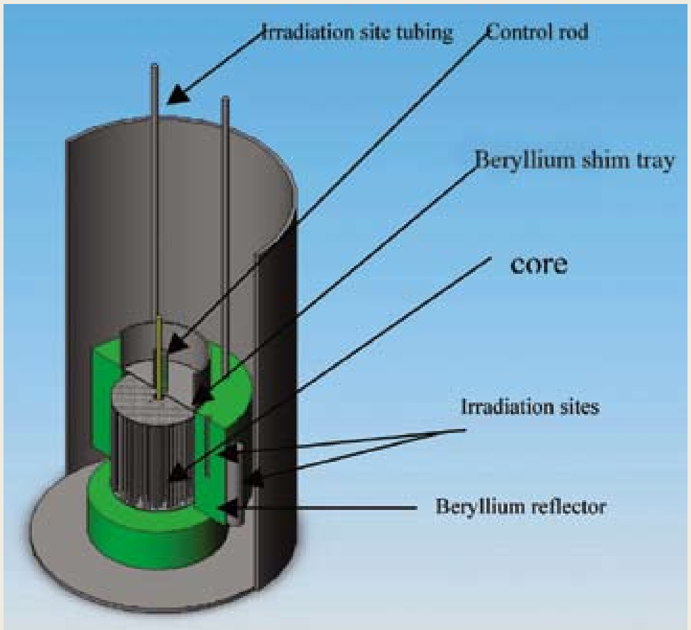

Figure 2: Simple Representation of the SLOWPOKE -2 Reactor.

Goal of the Research

Since some of the SLOWPOKE-2 reactors in service in Canada need to be refuelled in a near future, it would be interesting to study the feasibility of replacing the actual heterogeneous fuel core of the present SLOWPOKE-2 by a reservoir containing a homogeneous fuel for the production of Mo-99.

The study will look at the following items:

1. By using the MCNP 54 probabilistic nuclear reactor physics code, develop a series of parameters required for an homogeneous fuel and evaluate the uranyl sulfate concentration of the aqueous solution fuel in order to keep a similar excess reactivity;
2. verify if the homogeneous reactor will retain its inherent safety attributes; and
3. with the new dimensions and geometry of the fuel core, observe whether the natural convection will still effectively cool the reactor using the modeling software based on the finite element method FEMLAB®[5], or not.

The results obtained will be the stepping-stone for further development of a Homogeneous SLOWPOKE Reactor for research purpose and/or production of commercial radioisotopes.

The SLOWPOKE-2 Reactor

The Safe Low-Power “Kritical” Experiment (SLOWPOKE) reactor was developed by Atomic Energy of Canada Ltd (AECL) in the late 1960’s. This reactor is a low power pool-type reactor, and is inherently safe. Because of its low excess reactivity and large negative temperature and void coefficients, it is licensed in Canada for unattended operation while remotely monitored without the need to have its operators extensively trained. The safety features can be summarized in the negative effect on the reactivity of a temperature increase or of a loss of its coolant/moderator (water). Figure 2 displays the geometrical arrangement of the SLOWPOKE-2 reactor.

Homogeneous SLOWPOKE Reactor

In order to evaluate the feasibility of transforming the SLOWPOKE -2 reactor into a homogeneous reactor, several changes need to be made to the present design to allow the introduction of a homogeneous fuel without modifying the main structure and the original annular beryllium reflector. The changes being investigated are as follows and can be seen in Figure 3:

a. removal of the beryllium shims and tray;
b. removal of the actual fuel core and control rod;
c. insertion of a fuel core with homogeneous fuel. The core is made of a Zircaloy-4 container with an orifice in the centre vertical axis for the insertion of a control rod and cooling. The core is filled with an aqueous solution of uranyl sulfate. It is possible to extend the core height above the 22 cm height of the present core.
d. possibility of increasing the height of the beryllium reflector to follow the height of the core by adding an addition to the top of the annular reflector if the homogeneous reactor core is taller than the original core; and
e. modification of the control rod to provide sufficient negative reactivity to shut down the reactor at all times.

Modeling of Reactor

First an MCNP 5 model was constructed, to determine if the homogeneous reactor will have a positive excess reactivity without modifying the actual architecture of the reactor. To do this, so the actual core is replaced with a container made of Zircaloy-4 filled with a homogeneous fuel composed of a solution of water and uranyl sulfate. Several simulations were conducted by varying the volume of the container by changing its height to a maximum of 50 cm, which is dictated by the height of the lower core container (about 50 cm of height for the core),and the concentration of the solution to a maximum of 4 M of uranyl sulfate. The height of the beryllium reflector followed that the container. During the process, the concentrations of the solution were kept to a minimum to avoid corrosion of the container.

When the size of the reactor and the concentration of the fuel solution were established, the parameters were fine tuned to allow the addition of the control rod and the fuel treatment piping. Table 2 displays a summary of the final design. To validate the results, a model was constructed with the code WIMS-AECL[6] with the dimensions at Table 2. By adjusting the axial buckling, the results obtained with the 2-D representation by WIMS-AECL were similar to the results obtained with 3-D representation by MCNP-5.

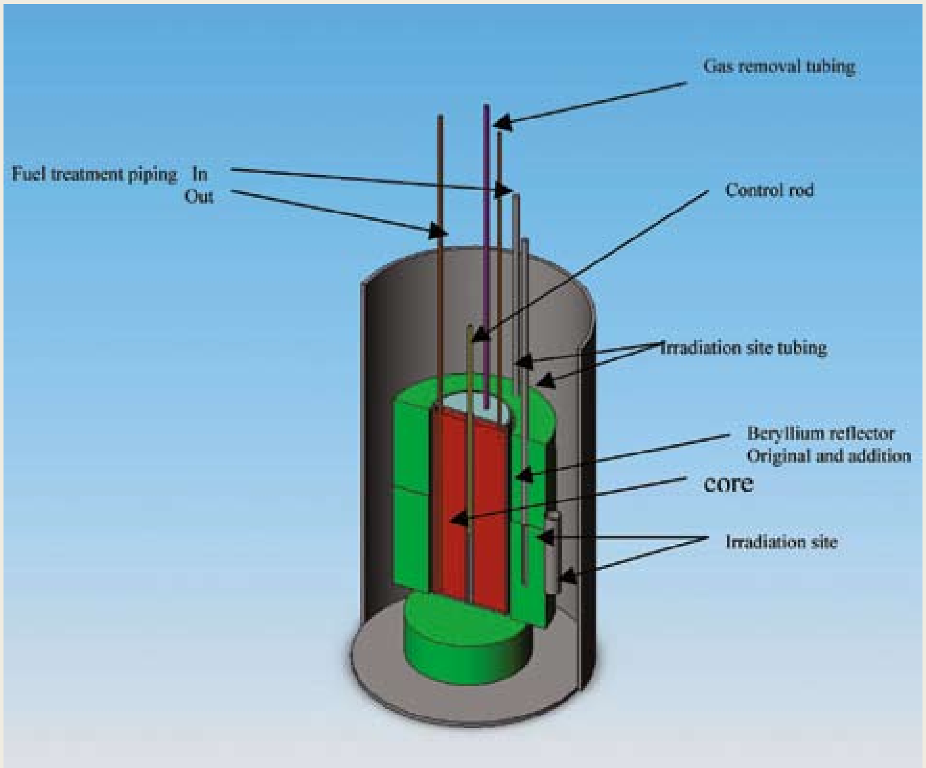

Figure 3: Simple Representation of the Homogeneous SLOWPOKE Reactor

Effects of Temperature and Control Rod

With the concentration and dimensions listed in Table 2, the inherent safety of the reactor was verified. Simulations were conducted by varying the temperature of the reactor using both MCNP-5 and WIMS-AECL. Figure 4 displays the effects of the temperature on the excess reactivity of the reactor. The results support the safe characteristic of the homogeneous reactor and that the reactor has indeed a negative reactivity factor at high temperature.

With the same method at the operating temperature, the effects of the control rod position were simulated with MCNP-5. Figure 5 displays these results. The results demonstrate that the use of the control can indeed shut down and control the reactor effectively.

Cooling of the Reactor

Since the reactor core design has changed significantly, a heat transfer study was conducted to evaluate if natural convection alone will be sufficient to cool the reactor. The study was conducted using the finite element based modeling software FEMLAB®. To save on computing time, the model was transposed into a two dimensions model, where the non-isothermal flow equation (variation of the Navier-Stokes equation) is coupled with the energy balance equation combined with the physical properties of each of the materials.

Figure 6 presents the temperature distribution inside of an axial slice of the fuelled core at steady state from the centre of the

Table 2: Summary of Reactor Characteristic

Reactor Parameters	
Core height	48.8 cm
Core radius	10 cm
Core cladding thickness	3 mm
Cladding material	Zircaloy-4
Control rod orifice radius	0.73 cm
Control rod material and radius	Cadmium 2 mm
Control rod cladding thickness	Al 2 mm
Fuel volume at 40°C	15.244 l
Beryllium reflector annulus	
inner and outer radius	11 cm / 21 cm
Beryllium reflector annulus height	48.8 cm
Fuel	Uranyl Sulfate solution in water
Fuel enrichment	20%
Fuel Concentration	1.65 M
keff	1.00361 MCNP 5 result
Thermal power	20 kW
Operating temperature at steady state	313 K

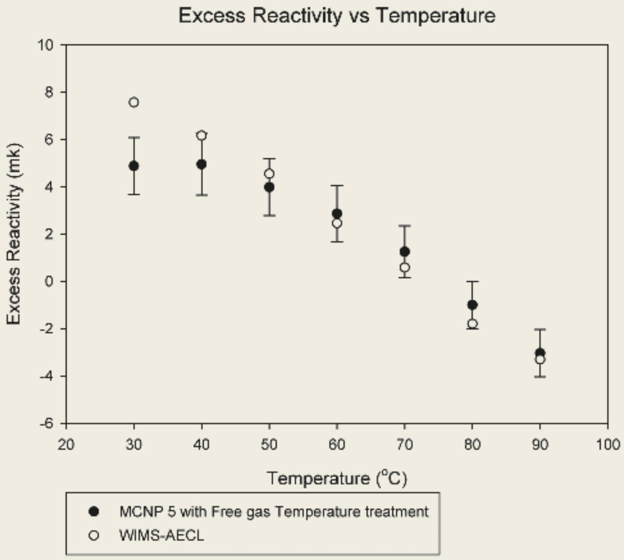

Figure 4: Effect of Temperature on Reactor Excess Reactivity using AECL- WIMS and MCNP-5

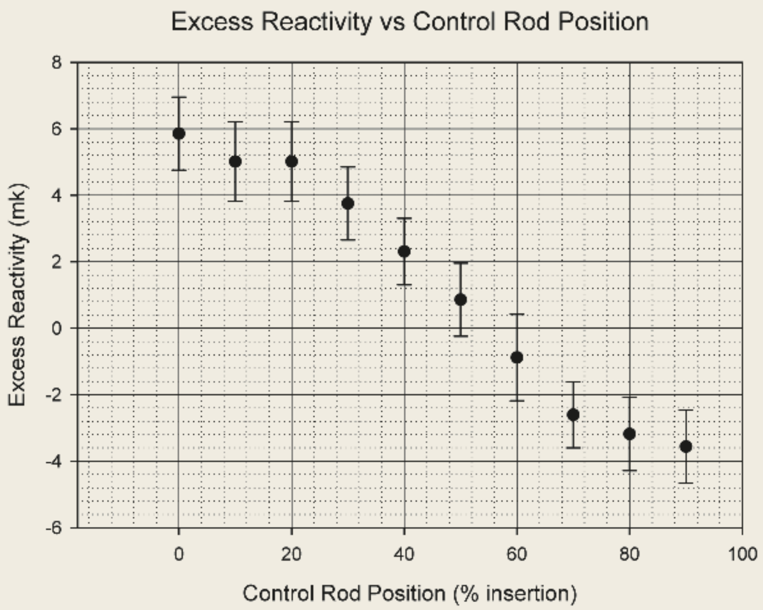

Figure 5: Excess Reactivity vs Control Rod Position using MCNP 5

reactor (centre of the control rod orifice) to the reflector (refer to Figure 3). The results show that natural convection is sufficient to cool the reactor to a temperature similar to that of the SLOWPOKE-2 reactor operating at full power, which is 315 K.

Discussion of Results.

Neutronics Results:

It is impossible to verify the results obtained from the simulations to corresponding values obtained experimentally, since no homogeneous SLOWPOKE reactors have been built and operated, the study had to use two different modeling codes, MCNP 5 and WIMS-AECL. MCNP 5 is a probabilistic code that solves the neutron transport equation using the Monte Carlo method for a three dimensions model, and WIMS-AECL is a deterministic code that solves the transport equation in two dimensions using the collision probability method. The legitimacy of the validation of the model with those two codes is improved by the similar geometry description provided as of the input file of both codes. This is due to the simplicity of the reactor architecture, which is composed of a series of concentric cylinder of different material as pictured in Figure 3.

MCNP-5 is a reliable code. Pierre[7] successfully modelled the present SLOWPOKE-2 reactor using MCNP-4, and compared his result to commissioning results of the RMC's SLOWPOKE-2 reactor. The simulation, even with a cruder version of MCNP, proved to be faithful to the actual reactor performance. Since the Homogeneous Reactor is simpler to be modelled due to a simpler geometry, and since a more advanced version of MCNP was used, the confidence on the result precision has increased.

Past work from Cole[8] and Lamarre[9] have established an error + 5% when WIMS-AECL is used. Since WIMS-AECL code is based on a two-dimensional representation, an additional +1% is added for not explicitly accounting the third dimension. The error comes from three sources: one source of error comes, as mentioned, from the two dimensional model that simulates a three dimensional reactor. The second source of error comes from the fact that WIMS-AECL is a lattice cell code, in which one cell of an infinite number of cells in the reactor is represented by the code. Because the Homogeneous SLOWPOKE is built as one cell, the reflective boundary condition at the limit of the cell is changed from a mirror-type boundary to that of a non-reflective "void" boundary condition to allow for those neutrons to escape without any possibilities of back scattering and re-entering the reactor. The last source of error comes from the assumptions made in the codes, from two correction methods: one correcting the diffusion coefficient using the Benoist method and the other accounting for the neutron leakage by determining the radial and axial buckling.

In this case, the axial buckling of WIMS-AECL code was artificially adjusted such that the criticality results (ie K_{eff}) obtained by WIMS-AECL matches the value of MCNP-5. Then the temperature effects of both code were compared (Figure 4), and since the trends of both curves are similar, one can conclude that both codes appear accurate in modelling the homogeneous SLOWPOKE reactor.

Heat Transfer Model

The uncertainty of the results provided by FEMLAB® depends on the precision of the equations used as input and the tolerances set in the problem solving method. For the heat transfer analysis of the reactor at steady state, a relative tolerance of 0.1% and absolute tolerance of 0.0 1% were used. Therefore the error on the results originates from two possible causes. First, like the case of the other software used to analyse the criticality of the reactor, the geometry of the problem represents a source of the error. As for MCNP 5 and WIMS-AECL, the reactor geometry is simple to reproduce with the graphic user interface; therefore the error coming from the construction is considered small. Lastly, the error may come from the input data and equations. The majority of the parameters and equations used in the FEMLAB® problem definition come from reliable data sources that were derived mostly from credible experimental studies. The only data that had to be approximated was the equation of the influence of temperature on the viscosity of uranyl sulfate, where the equation was curved fitted using only three data points. A parametric study was carried out to evaluate the sensitivity of the results on the values of the equation's coefficients, and confirmed the reliability of the FEMLAB® calculations.

Conclusions

The aim of this work was to study the feasibility of converting a SLOWPOKE-2 reactor into a homogeneous inherently safe reactor. By using a numerical model of the reactor with the code MCNP 5, it was possible to reach criticality for the homogeneous reactor by increasing the height of the reactor. It was found that the concentration would reach saturation point if the original height of 22 cm were used, therefore a height of 48.8 cm was determined as necessary to keep the concentration to a minimum value to avoid corrosion problems and yet obtain a reactor

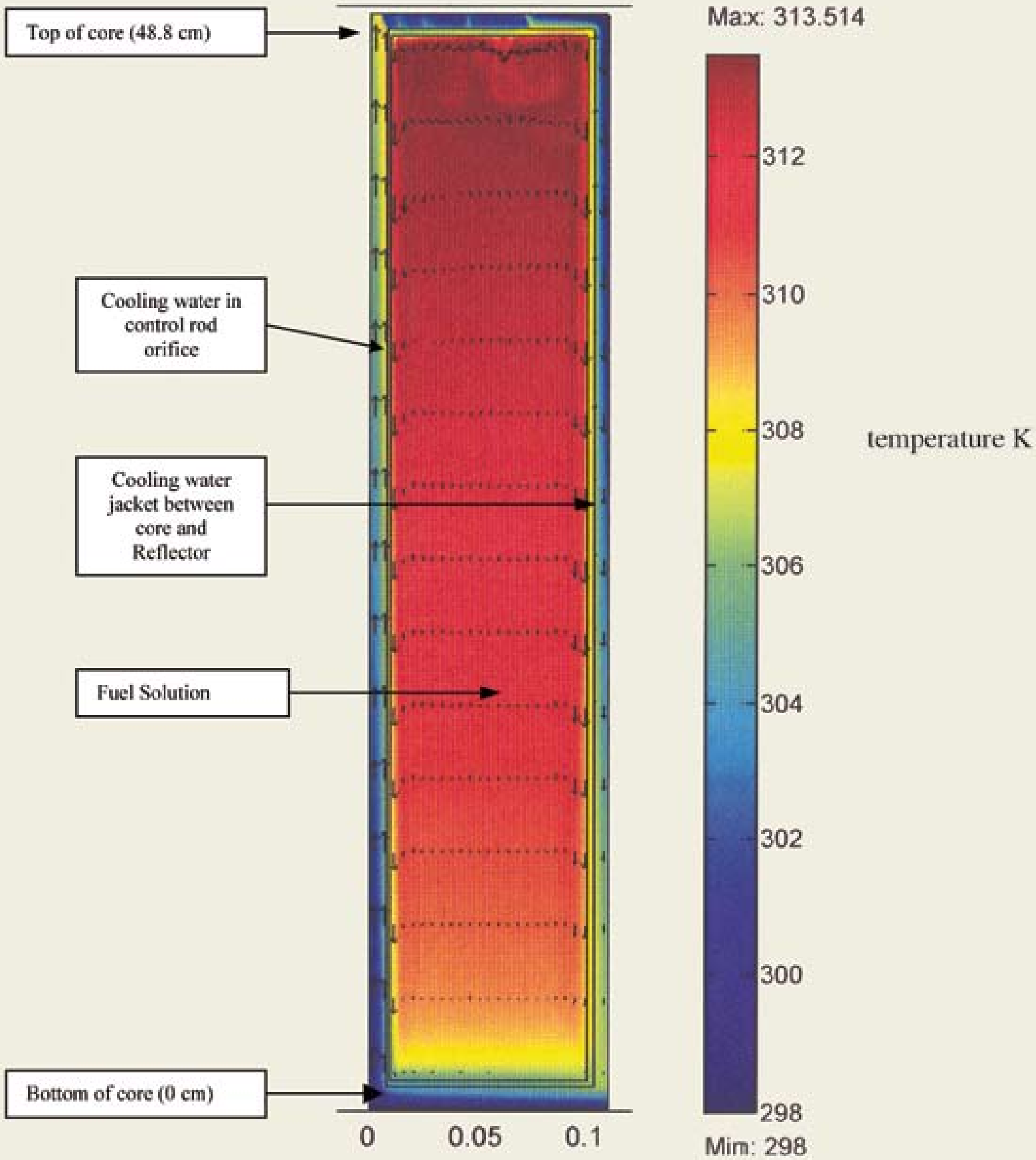

Figure 6: Flow Pattern and Temperature Distribution of Fuel Mixture and Cooling Water at Steady State using FEMLAB®

with sufficient positive excess reactivity. Therefore, for a height of 48.8 cm, the concentration would vary between 1.6 M and 1.65 M for a resulting excess reactivity between 1 and 6 mk.

In this work, the necessary condition for inherent safety of the reactor was verified and confirmed since an increase of the temperature has indeed a negative effect on the reactivity such that the reactor would become sub-critical at a temperature of 75°C . In addition, it was determined that a single control rod was sufficient to shut down the reactor by itself, without the need of additional shutdown system.

Lastly, a heat transfer study was conducted to confirm that natural convection would be able to cool the reactor down enough to avoid localized boiling of the fuel mixture and cooling water. It was found, using the simulation program FEMLAB®, that the fuel would reach a maximum temperature of 40°C at steady state, which is well below the atmospheric boiling points of both the cooling water and the fuel solution.

With the change of its fuel, an increase of its core height and reflector the reactor and the addition of few ancillary equipment such as an extension of the annular beryllium reflector, it is indeed feasible to modify the SLOWPOKE-2 reactor into a homogeneous reactor using a solution of uranyl sulfate and water.

It is recommended the research continue with a emphasis on the on the safety of the reactor during power transients, the control system to be used and on the material to be used for the reflector addition.

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A very public debate: the nuclear industry in Port Hope

by Bart Hawkins Kreps

Ed. Note: *Public acceptance in Canada of things nuclear has increased but there is one place where the debate still rages – Port Hope, Ontario – the home of Cameco Corporation's uranium conversion facility and Zircatec Precision Industries' nuclear fuel fabrication plant. Although he has not worked in the nuclear field, Bart Hawkins Kreps became a member of the Canadian Nuclear Society in 2004, shortly after moving to Port Hope, Ontario, and becoming active in the ongoing public debate about Cameco and Zircatec. Following is his account of the current status of that debate. He has a website: www.anoutsidechance.com*

A view of Cameco's facility on the waterfront of Port Hope.

There probably aren't many small towns where the daily newspaper's letters page is regularly filled with discussions of the oxidization potential of freshly reduced UO_2, or the caloric consequences of an unplanned criticality.

But for the past two years, debates on nuclear issues have dominated not only local newspaper content, but also discussions in the municipal council chamber, in Port Hope, Ontario.

Just over two years ago a new group, *Families Against Radiation Exposure (FARE)* distributed a flyer entitled *"Enriched Uranium? Enriched Risk"*. A year later, FARE claimed a victory when Cameco dropped its plan to blend Slightly Enriched Uranium (SEU) in Port Hope. But in the months since, FARE's campaign against local nuclear facilities has only intensified. Among the citizens of Port Hope, it is widely believed that FARE's goal is to rid the town of any active nuclear industry.

A brief background

Cameco's Port Hope facility was part of a crown corporation for most of its 70-year history. *[It began in the early 1930s as a radium refinery owned by Eldorado Gold Mines. During the Second World War it was taken over by the Canadian government to refine uranium mined in the NWT primarily for the US Manhattan Project. In 1988 Eldorado, then called Eldorado Nuclear Limited was merged with the Saskatchewan Mining Development Corporation to form Cameco Corporation, which was privatized in 2002.]*

In the early years, unwanted byproducts were dumped in many locations around the community. In the 1970s, the federal government recognized that these practices should not have been allowed, and took responsibility for the clean-up. Low-level radioactive waste has been consolidated in a small number of fenced-off locations. The transport of this material to a state-of-the-art storage site is slated to begin in 2008.

The actual health effects of this history are open to debate. Two Health Canada studies found no overall increase in cancer in Port Hope as compared to other Ontario towns. But the call for more in-depth health studies has been persistent.

Some citizens have campaigned against the nuclear industry for decades, and make no bones about their deep distrust of nuclear business interests and regulatory personnel. By contrast, many citizens regard Cameco and fuel-bundle manufacturer Zircatec as good employers, community philanthropists, and industries which now operate with the highest standards of environmental protection.

In 2004, the phrase "Slightly Enriched Uranium" brought the divisions into sharp relief.

What does FARE stand for?

FARE walks like an anti-nuclear group and talks like an anti-nuclear group. But the group's leaders vigorously deny that the group is anti-nuclear.

Some of FARE's most active members make no secret of their anti-nuclear views. For one of FARE's first public meetings, in June 2004, the featured speaker was long-time anti-nuclear activist Gordon Edwards.

FARE's official goal – "to end radioactive pollution in Port Hope" – sounds more sensible than its name, Families Against Radiation Exposure, given that there is radiation exposure everywhere on earth. But an implied equivalence between "radioactive exposure" and "radioactive pollution" serves FARE's purposes very well.

1 *Port Hope Evening Guide*, page 4, May 31, 2006

FARE president John Miller heads the newspaper journalism department at Ryerson University. He knows how to plow through stacks of documents in search of a quotable phrase. In discussing the reports of the committee on Biological Effects of Ionizing Radiation (BEIR), Mr. Miller cited the statement that "a preponderance of scientific evidence shows that even low doses of ionizing radiation are likely to pose some risk of adverse health effects."

He then offered his own translation: "Essentially, the report said there is no safe level of radiation exposure."[1] Would Miller therefore conclude that common household smoke detectors, and dental X-rays, are unsafe? He has declined to answer such questions.

FARE's reaction to a study by Jacques Whitford Ltd. was a prime example of selective reading. The town council had contracted Jacques Whitford to review Cameco's Environmental Assessment for the SEU project. The executive summary of the review stated: "Jacques Whitford concurs with the conclusions that the results of the assessment identified no significant residual environmental effects of the proposed SEU Blending Project, including effects from accidents and malfunctions, effects of the environment on the Project, and cumulative environmental effects." The report also mentioned a few areas where Cameco's EA report should be strengthened.

FARE's response was to run a newsletter article headlined "Municipal peer review finds fault with Cameco." The article said that "FARE supports many findings in a municipal peer review report which says that Cameco's draft Environmental Assessment contains serious deficiencies." The peer review's major conclusion was not mentioned.

Terror alert in Port Hope

SEU is more radioactive than natural uranium. If one believes no level of radioactivity is safe, then a marginal increase in radioactivity may be seen as highly important. However, the possible connection of "enriched" with weapons has received even more attention.

The FARE website says, "because of its potential use in a nuclear bomb program, enriched uranium is a greater security risk than natural uranium." It also says that an "unplanned chain reaction is called a 'criticality accident'. Such an accident is simply not possible with natural (un-enriched) uranium."

Furthermore, the site states, "The heat energy released by … a 'criticality' is sufficient to vaporize metals…. The advanced fuels mentioned above (from SEU to MOX) can suffer criticality accidents if they come in contact with water."

Cameco representatives and others pointed out in detail why the above statements were far-fetched. Nevertheless, the risk of terrorism is cited frequently, particularly by Port Hope councillor John Morand, one of FARE's founders. Mr. Morand chairs the town's Protection to Persons and Property committee. He is not shy about citing his previous high-rank positions, including a recent stint as CEO of the Toronto Port Authority. He says that his experience makes him qualified to comment on security issues, and his speeches to regulatory officials sometimes include pointed references to possible lawsuits.

At least twice, Morand has referred to the Cameco plant, in writing, as potentially "the world's largest dirty bomb." He has also cited the danger of a criticality at the nuclear fuel manufacturing plant of Zircatec Precision Industries Inc. also in Port Hope, where SEU is slated to be assembled into fuel bundles. In his brief to the CNSC in February 2005, Morand said: "A small criticality at 5 per cent is a sphere of 35 kilograms, which would be about the size of a beach ball… A small criticality at 1 per cent would be somewhere between 1,200 and 1,500 kilograms…"

Morand posed this scenario: "So if you had an individual with a bit of a problem, there is the possibility to move that 35 kilograms of material from one area to the other and drop it into a drain or toilet. Then you have a moderator."

In response, Zircatec president Lloyd Jones pointed out: "when you are talking about, for example, 1 per cent material, which is the bulk of material that would be used in this future line ... that is about 1,700 kilograms, which is about the size of a car, weight of a car. It is very difficult to lug that size and volume of material into a washroom and find a sink or toilet large enough to put it in to make it go critical while at the same time holding it in a spherical shape in order to have the ideal condition for a criticality to take place."

The CNSC staff at the hearing accepted Mr. Jones' explanation. But given FARE's open distrust of the CNSC, we can expect to hear some variant of the "criticality in the loo" scenario again.

A burning issue… or at least, an oxidizing issue

Starting in the summer of 2005, FARE issued frequent statements claiming that the CNSC was negligent, because they had stated that Cameco's fire protection provisions were "unacceptable", and yet Cameco had been given extensions in correcting the alleged deficiencies. Mr. Miller accused the CNSC of "reckless disregard for safety". But when this writer asked Mr. Miller to clarify what he thought Cameco should be required to do he declined to answer.

In the following months, many people, including fire fighters, wrote that emergency preparations in Port Hope were quite adequate.

To Mr. Miller the issue was clear-cut. In March of 2006, he wrote in the Port Hope Evening Guide that "If a fire broke out tomorrow at Cameco or Zircatec involving radioactive or hazardous materials, nobody in the community could put it out. We'd have to wait for trained firefighters and equipment to arrive from Toronto. We know this because the municipality's fire chief has said so."

In the same letter, he praised the recently appointed fire chief with the words "Frank Haylow is about the only public figure standing up for accuracy and common sense …."[2]

Such talk was too much for some long-serving firefighters to

2 *Port Hope Evening Guide,* March 2, 2006.

3 *Port Evening Guide,* March 29, 2006, letter by Jim Boughen, who had been Chief of the Port Hope Fire Department for 19 years.

4 *Port Hope Evening Guide,* March 2, 2006.

bear. A recently decorated volunteer, Bob Cranley, wrote a letter disputing the claims of FARE and of the new fire chief. And the former fire chief, who had served in that position for 19 years, also voiced his confidence in emergency preparations.[3]

Matters quickly came to a boil. Mr. Cranley was dismissed from the force, there was an outpouring of public support for Mr. Cranley, Mr. Cranley was re-instated.

Meanwhile, Mr. Miller continued to question the flammability of uranium. Over several months, various writers had explained that uranium dioxide does not burn in the sense of going up in flames, but that under certain conditions it will spontaneously oxidize, get warm, and then cool down. But Mr. Miller wanted a simple yes-or-no answer. In a letter to the editor, he fumed: "The truly alarming thing is that nobody at the CNSC seems to know or care who's right about the rather basic question of whether or not uranium can be set on fire."[4]

Twenty-eight year Cameco veteran Glen MacKenzie made another effort to clear the air: he cited the Material Safety Data Sheet on UO_2. He noted that "the MSDS states that UO2 is not flammable." In response Mr. Miller claimed that FARE had finally discovered the truth about UO_2: "Rather than taking Mr. MacKenzie's word for it, I have obtained the MSDS sheets that he refers to, dated May 2001. They say that 'freshly reduced UO_2 powder is pyrophoric and will react with the oxygen in air and burn.'"

In fact, the two-page MSDS states explicitly that UO2 is not flammable. But in Mr. Miller's reading, the MSDS was the smoking gun, which uncovered the "misinformation put forward by people who should know better."[5]

Not In

Can FARE be termed an anti-nuclear group? Not in their view. A number of FARE spokespeople, including Mr. Miller, Mr. Morand, and board member George Clements, have stated that they are personally pro-nuclear. From the beginning, FARE has cast its net as widely as possible to gain support, and then focussed only on one very limited, but very strategic, goal at a time.

In the early days of the anti-SEU campaign, the specific strategic goal was to get a full Environmental Assessment panel review of the project. In those months, Mr. Miller would sometimes say he didn't have enough information to be for or against the SEU project; the important thing was to have full scrutiny, which only a Panel Review could provide. FARE also minimized the time frame, and the costs to taxpayers, of such a process.

When Cameco announced they would buy SEU elsewhere, FARE was quick to claim credit for a victory. And some members openly celebrated the first step in getting the nuclear industry out of town.

FARE waited until the summer of 2006 to launch an open campaign around the issue of SEU processing at Zircatec. As late as August 2006, an angry Mr. Miller answered a newspaper editorial by writing, "you twist words in an attempt to prove that FARE really wants Cameco to leave town. For the record, we have not called for that because we do not feel we have the facts to justify such a move. There are too many unanswered questions."

Asking questions is the group's defining characteristic. Its printed logo is a large question mark – albeit a question mark drawn as an ugly distorted inkblot, which makes a pretty definite emotional statement. In the anti-SEU campaign, FARE effectively choked the project with questions, 623 of them to be precise. Although many of the questions had only a tenuous relationship to the SEU proposal, and there were readily available answers for many of the others, FARE insisted that all 623 questions must be answered.

Port Hope's unique circumstances made that strategy very effective. For many reasons, the local soil is fertile ground for fear, uncertainty and doubt.

Widespread contamination in decades past has left ambiguous results. FARE explicitly ties the issue of licences for Cameco's and Zircatec's present-day activities to lingering worries about the past. The latest FARE newsletter states as the first current goal: "Stop any new production of enriched uranium until Port Hope residents get convincing proof that 70 years of exposure to radiation has not been harmful to their health." It is inconceivable that all FARE members could ever be "convinced" of such a thing.

FARE highlights public uncertainty on the issue of "natural versus artificial" radiation. Its members argue that the fine particles of uranium dust that still escape the HEPA filters at Cameco constitute a qualitatively unique health threat.

Finally, there is the unaesthetic set of industrial buildings dominating what might be an attractive small-town harbour. Even among those who feel that Cameco's activities pose no danger, there are those who would much rather see a non-industrial zoning. In their view, it would be a good thing if Cameco's facility were replaced with marinas, restaurants, and perhaps a mix of office space and condos.

So far, just raising questions has been a most effective tool. The clear lesson of the SEU battle so far has been that FARE doesn't have to prove anything. By getting a sufficient number of its questions onto the regulatory agenda, FARE made the SEU blending proposal uneconomical. That strategy doesn't appear to have changed for round two: FARE's current goal is to extend the licensing process, so that Zircatec will be required to submit a full Environmental Assessment in order to process 1% enriched uranium.

Cameco Corp., which completed its acquisition of Zircatec in February, has expanded an already extensive public consultation program. Several forums have been held this year, each one bringing together scores of Port Hope residents. The discussions have sometimes been heated, but the company is continuing with forums that are projected to include a wide variety of industry experts and critics.

FARE takes credit for "forcing" the company to consult with the community. On the other hand, FARE members including Mr. Miller have openly worried that by participating in the consultations, they are being co-opted by a corporate public relations campaign. One can only hope that in the future, Port Hope's nuclear debate will generate as much light as it generates heat.

5 *Port Hope Evening Guide,* April 17, 2006. This letter, and the MSDS itself, remain posted on FARE's website as of this writing, and are highlighted on the site's opening page, www.ph-fare.com

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History

Heavy Water at Trail, British Columbia

by J.E. Arsenault[1]

Introduction

Today Canada stands on the threshold of a nuclear renaissance, based on the CANDU reactor family, which depends on heavy water as a moderator and for cooling. Canada has a long history with heavy water, with commercial interests beginning in 1934, a mere two years after its discovery. At one time Canada was the world's largest producer of heavy water. The Second World War stimulated interest in this rather rare substance, such that the worlds largest supply (185 kg) ended up in Canada in 1942 to support nuclear research work at the Montreal Laboratories of the National Research Council. A year later commercial production began at Trail, British Columbia, to support work that later became known as the P-9 project, associated with the Manhattan Project.

The Trail plant produced heavy water from 1943 until 1956, when it was shut down. During the war years the project was so secret that Lesslie Thomson, Special Liaison Officer reporting on nuclear matters to C.D. Howe, Minister of Munitions and Supply, was discouraged from visiting Trail operations. Thomson never did visit the Trail facility during the war.

In 2005 the remaining large, tall concrete exchange tower was demolished at a cost of about $2.4 million, about the same as it cost to construct the facility about 60 years ago. Thus no physical evidence remains of this historic facility and another important artifact from Canada's nuclear history has disappeared forever. It is planned to place a plaque at the site at some point in the future.

Figure 1. Gutted P9 heavy water exchange tower in final stage of demolition, April 2005. (Photo courtesy of The Trail Daily Times)

Nuclear Science Development

In 1904, Ernest Rutherford's groundbreaking book *Radio-Activity* was published. The book was written while he was Professor of Physics at McGill University and it compiled and analyzed all the important discoveries regarding the new phenomenon of radioactivity up to that time. In a sense the publication laid a solid foun-

1 Jim Arsenault is a recently retired reliability engineer who has developed a keen interest in the early history of Canada's nuclear program. This is the second of his contributions to the CNS Bulletin, the first being one on early uranium mining, *"The Eldorado Radium Silver Express"*, in the December 2005 issue, Vol. 26, No,. 4

dation for the development of atomic science as a distinct field of investigation and set the stage for the many discoveries that followed rapidly in research laboratories around the world.

1932 was another historic year in which two entities, the neutron and heavy water, were discovered and, thereafter, slowly but inextricably became entangled as access to the energy stored in the atom became theoretically and then practically possible.

The neutron was discovered by James Chadwick at Cambridge University, U.K., in 1932, when he proved the existence of a neutral particle located in the nucleus, as predicted by Rutherford. As a result, many laboratories started to explore atomic structure using the penetrating neutron. In 1934 Enrico Fermi (in Italy) progressively bombarded most of the elements in the periodic table with neutrons, thus creating numerous radioactive isotopes.

Heavy water (deuterium oxide) was discovered and announced in 1933 by Harold Urey and colleagues at Columbia University, New York, in conjunction with their hunt for the hydrogen isotope deuterium (with a nucleus consisting of a single proton and neutron). Heavy water was first produced commercially in small quantities in 1934, by Norsk Hydro in Norway, using electrolysis of water, but for a long time it remained a laboratory curiosity.

In 1938 Otto Hahn and Fritz Strassman, working at the Kaiser William Institute of Chemistry in Berlin, obtained results (which were announced in 1939) that led them to conclude that while bombarding uranium with neutrons, radioactive barium was produced as a byproduct–a most unexpected result. In the same year Lise Meitner and Otto Frisch, while vacationing in Sweden, explained (announced in 1939) that the atom had been fissioned, or split, with an accompanying release of energy. Thus, by very early 1939 it became widely speculated that if more neutrons were released than absorbed during fissioning, a chain reaction would be possible and a large amount of energy would be released.

Many researchers commenced efforts to determine the physical configurations or possible reactor arrangements required to tap nuclear energy to produce a controlled reaction (power) or an uncontrolled reaction (explosion). At the Collège de France work had progressed to a point with slurries of uranium oxide and water where it became clear that sustained nuclear reactions could only be achieved with materials of low neutron absorption. Because it is a low absorber of neutrons, experiments with heavy water began in 1940 at the Collège, which were continued at Cambridge University after Paris was overrun by Germany in June 1940. Work continued there until it was moved in November 1942 to the Montreal Laboratories of the National Research Council, including 185 kg of heavy water manufactured by Hydro Norske.

Contemporaneously at Columbia University, Enrico Fermi was experimenting with lumps of uranium oxide (obtained from Eldorado Gold Mines Limited of Toronto) embedded in graphite as a moderator. Similarly, George Laurence began part-time experiments in the Ottawa Laboratories of the National Research Council in March 1940 and experienced the usual purity problems. Laurence visited Columbia in December 1940 and became familiar with the work there by Fermi and came very close to building the first working nuclear reactor in the world.

By early 1940 most of the theoretical considerations with respect to uncontrolled nuclear reactions were captured in a secret paper by Rudolph Peierls and Otto Frisch working at the University of Manchester, which came to be known as the Frisch/Peierls Memorandum. For the first time it was shown theoretically that only kilogram amounts of the isotope of uranium U235 would be necessary to create a large explosion and practical methods were suggested for its manufacture.

The element plutonium was discovered by Glenn Seaborg in the winter of 1940-41 at the University of California at Berkley, while he was examining products formed by the bombardment of uranium oxide with deuterons from a cyclotron. Soon it was found that the isotope Pu239 was even more fissionable than U235 and the die was cast such that these two isotopes would become essential ingredients in the development of atomic energy in peace and war.

By the end of 1941, with war raging in the European and the Pacific theatres, the centre of gravity of atomic research shifted to the U.S. and it was pursued there vigorously on all fronts, with the sole purpose of producing an atomic weapon. At that time atomic research was carried out by the Office of Scientific Research and Development (OSRD) and steps were taken to ensure enough fissile material for the manufacture of weapons. The uncertainty with industrial processes lead the OSRD to pursue a conservative approach which built in a great deal of redundancy into the production program. Many research options were closed after June 1942 when all atomic activities were taken over by the U.S. Army Corps of Engineers but parallel paths continued to be pursued to reduce uncertainty. To administer the program the Army created the Manhattan Engineer District (MED) and thus the Manhattan Project became into being.

To produce Pu239, reactors coupled with chemical extraction provided the required route and they could be based on either heavy water or graphite. In April 1942 the OSRD had settled on graphite as it was readily available, as opposed to heavy water which was not easy to produce in quantity. In December 1942 Fermi at the University of Chicago brought the world's first atomic reactor (Chicago Pile) CP-1 into operation using graphite. Based on this success, the Corps decided to proceed with the construction of large graphite reactors at Hanford, Washington. To provide a backup in case of problems with graphite, the University of Chicago was contracted to design a heavy water experimental reactor and as a result there was a substantial effort to produce the heavy water.

The first heavy water was produced commercially by the successive electrolysis of ordinary water, based on the fact that the hydrogen given off during electrolysis contains five or six times less deuterium than in the residual electrolyte. Because heavy water is present in ordinary water in the ratio of about 1/4500, this method alone is very inefficient requiring 50 tons of ordinary water to produce 1 kg of heavy water. Ways were sought to increase the amount of deuterium in ordinary water before final concentration by electrolysis.

One method is based on an exchange reaction between ordinary water and hydrogen in the presence of a catalyst, in accordance the following equation, where g and l represent gas and liquid respectively:

$$H2(g) + D2O(l) :: D2(g) + H2O(l)$$

The substances on the left-hand side, which includes deuterium oxide (heavy water), are favoured over those on the right

Table 1: Contract Summary for Trail Heavy Water Plant

Origin	Item	Company	Date	Activity
OSRD	Letter of Intent	CMS	420225	$5000. Electrolysis studies for a HW plant
OSRD	Letter of Intent	CMS	420501	$50,000. Existing plant modification studies for a HW plant
OSRD	Contract OEMsr-797	CMS	430104	Replaced Letters of Intent. Studies and prelim. eng. for large-scale HW plant
OSRD	Authority to Proceed	E.B. Badger, Boston	4205--	Design and Eng. of a HW exchange unit
MED	Contract W-7401, eng-13	Stone/Webster,New York	420629	Gen. arch., eng., const. and mgr. services
MED	Contract W-7405, eng-10	CMS	420731	Alterations to CMS property
MED	Contract W-7418, eng-70	CMS/Allied War Supplies Corp. (Cdn. Gov. Agency)	431203	No rent land lease. Seven parcels of land (0.474 acres)
MED	Contract W-7405, eng-11	CMS	420731	HW plant operation
Stone/Webster New York	Lump sum Contract C-819, No. 21	Universal Oil Products, Chicago	421121	Production of nickel-chromium catalyst
Stone/Webster New York	P.O. No. 44	J.T. Baker, Newark	421103	Production of platinum on charcoal catalyst

by a ratio of three to one at equilibrium. The reaction requires large amounts of hydrogen and the ammonia plant operated by The Consolidated Mining Refining Company Limited in Trail, British Columbia, was exactly what was required.

Consolidated Mining and Refining

With the discovery of copper-gold ore in 1890 near Rossland, British Columbia, a mining boom began in the area with the ore being shipped down the Columbia River from Trail Creek Landing (the early name for Trail) for refining in the United States. There were further discoveries of lead and lead-zinc ores, resulting in lead smelting at Trail and in 1906 a consolidation was effected, resulting in the formation of The Canadian Mining and Smelting Company of Canada Limited (Cominco or CMS for short).

CMS acquired the Sullivan Mine property near Kimberley in 1910. Prior to this many attempts were made to treat the lead-zinc ore but none were successful and initially CMS treated only the hand-picked crude lead ore at Trail. In 1916 CMC started a small electrolytic zinc plant at Trail and zinc was produced, although with difficulty. It was not until 1920, after three years of research, that CMS succeeded in handling the lead-zinc ore with a differential flotation process. By 1929 CMS became one of the world's largest producers of lead and zinc.

The Sullivan lead-zinc ore came with a high sulphur content which was removed by roasting. The smoke emissions from the Trail refinery drifted down-wind to the US causing some damage to vegetation. To look into the matter an International Tribunal was established in 1935 and it remained active until 1941. Under it the damage claim brought by the U.S. was reduced from $2 million to $78,000 plus interest at 6% until payment. Subsequently, a monitoring regime came into being. Even before the Tribunal, CMS had looked into solutions to the pollution problem and decided in 1926 to use sulphuric acid in excess of plant requirements as an ingredient to produce fertilizer. After years of research, a major construction project for a fertilizer plant began in 1930, based on sulphuric acid from the smelter emissions, ammonia, and hydro power from the Kootenay River.

Ammonia was made by combining nitrogen and hydrogen gases, with the nitrogen being extracted from the air. Hydrogen was produced at 99.9% purity from the electrolysis of water, using 3215 cells designed by CMS using a 28% caustic potash electrolyte. The hydrogen electrolysis plant located at Warfield, about two miles west of Trail, was capable of producing about 13 million cubic feet (or 36 tons) of hydrogen on a daily basis.

Trail Heavy Water Plant

As early as 1934, CMS began to investigate the properties of heavy water and had corresponded with the National Research Council but no commercial heavy water production started. Physical chemist Hugh S. Taylor (a British subject) at Princeton University, had been one of the first people to prepare heavy water in quantity. When the ORSD became interested in heavy water for reactor development, he began working with Urey (Columbia University) on mass production. After examining several methods, Taylor and Urey settled on the hydrogen-water catalytic exchange method and both men recognized that the CMS ammonia plant was the largest producer of electrolytic hydrogen in North America and that the plant, with suitable modifications, was capable of producing a half ton of heavy water monthly. By June 1941, Taylor was in contact with CMS and from that point events led to a commercial heavy water plant, that went into production 24 months later. By that time CMS had built up a very capable Chemistry Division, thus facilitating the development of the alterations to the ammonia plant to produce heavy water in commercial quantities. CMS employees Charles A.H. Wright, the first chemical engineering graduate of the University of British Columbia, and B.P. Sutherland were closely associated with implementation of the plant.

Initial contracts between CMS and the OSRD were for studies on electrolysis and conversion of the existing ammonia plant for making heavy water. Later contracts with the U.S. Government for alterations to CMS property, property leasing and plant operation were put in place by Stone and Webster of New York, who performed the overall engineering work on behalf of the Manhattan Engineer District when it was formed in June 1942. CMS directed the overall construction of the facility. Table 1 summarizes the CMS contracts. There were other related subcontracts between Stone and Webster and E.B. Badger, Boston (exchange unit design), Universal Oil Products, Chicago (nickel-chromium catalyst), and J.T. Baker & Company, Newark (platinum-charcoal catalyst).

"Construction of the plant started 1 September 1942. Good progress was maintained, uniformly ahead of or on schedule. The Secondary Concentration cell plant was transferred to operation 16 June 1943, and the entire plant was completed 30 June 1943." (MDH, p. 4.7)

The plant cost was $2,604,622 and, of this, $1,076,039 (or nearly half of the total) went to CMS and included a fixed fee of $1. The capital costs are summarized in Table 2.

Table 2. Capital Cost Summary for Trail Heavy Water Plant to 31 December 1946

Item	Cost (US$)
OSRD spending from War Department funds	204,198
New buildings/structures/extensions, including their equipment	1,677,532
Alteration/rearrangement of existing buildings/ equipment	212,793
Power and process lines	38,484
Purchase of catalysts	465,797
Undistributed (Stone and Webster/CMS)	5,818
Total Cost	2,604,622
These costs are also classified as follows:	
OSRD spending from War Department funds	204,198
Design and construction (Stone and Webster)	922,270
CMS	1,076,039
Items furnished by Government	124,873
Spare catalysts	277,242
Total Cost	2,604,622

"The description of the [Trail heavy water] process may be summarized as follows:

1. In the primary plant, normal water [was] led downward through three first stage towers wherein it [met] the upflowing hydrogen in the presence of a catalyst and thereby [increased] its concentration of heavy water, some of the light-hydrogen being displaced by the heavy-hydrogen component of the upflowing hydrogen. Essentially the same procedure [was] repeated in the second-, third-, and fourth-stage towers.
2. In the secondary plant, the water drawn down from the fourth stage of the primary plant (containing approximately 2.3% heavy water) [passed] successively through three stages or batteries of electrolytic cells. In the cells of each stage it [was] broken down electrically into hydrogen and oxygen; the liquid remaining in the cells [became] increasingly concentrated with heavy water, and the finally concentrated product, approximately 99.8% heavy water, [was] drawn from the third-stage cells.
3. Two catalysts were developed for use in the process: platinum-charcoal and nickel-chromium. The latter was planned and ordered as a reserve, but its production was discontinued when the platinum catalyst, manufactured by J.T. Baker & Co., was found to be satisfactorily efficient and durable." (Brown, p144)

Production of heavy water began in June 1943 and a mere 15 lbs were produced in that month. This heavy water was tested by Fermi at Chicago who confirmed that there was practically no neutron capture. Despite the many start-up problems encountered, production was doubled every few months so that finally 1050 lbs was produced in December 1944. Production remained at about that level until December 1946, as listed in Table 3. From December 1945 through March 1946, the plant upgraded heavy water sent to Trail from three shut down U.S. plants that were designed to supplement the Trail supply using different processes.

Table 3: Summary of Trail Heavy Water Plant Monthly Production (in lbs) from 1943 to 1946

Date	1943	1944	1945	1946
January		326	1055	950+*345*
February		513	910	825+*570*
March		467	973	1175+*131*
April		490	1095	1155
May		701	1100	1170
June	15	726	1005	1025
July	31	804	985	1056
August	27	650	1105	1305
September	61	824	1060	1132
October	137	905	1105	1080
November	125	955	1095	1330
December	275	1050	1100+*540*	852
Total(year)	671	8411	13128	14101
Total (cum.)	671	9082	22210	36311

Note: Quantities upgraded from U.S. sources from Dec. 1945 to March 1946 shown in italics

The total cumulative production up to the end of December 1946 was 36,311 lbs. Average monthly production costs were

$32,979 versus the $24,000 originally estimated and the plant produced heavy water at an average of $39 per lb.

The first heavy water reactor in the world, CP-3 (6.5 tons, 0.3 MW), went critical in May 1944 and was operated by the University of Chicago under the direction of the Canadian-born Walter Zinn and, therefore, would most likely have used all of the 1.2 tons of heavy water produced at Trail by that time. After the war Zinn was offered a position to run the Chalk River Laboratories but declined, as the U.S. counter-offer was very attractive.

Although the National Research Council had requested heavy water output from Trail in December 1942 for the Montreal Laboratories, none was made available until about September 1945, when the Zero Energy Experimental Pile (ZEEP) (5.0 tons, 0.0 MW) went critical at Chalk River. ZEEP was the second heavy water reactor in the world.

At the end of August 1945 a grand total of 32.2 tons of heavy water, sponsored by the MED, had been produced. By circa 1946, a total of 19.0 tons had been transferred to Canada for use in the ZEEP and the National Research Experimental Pile (NRX) (18.3 tons, 10 MW). The latter went critical in July 1947. It was a pilot-plant reactor, designed during the war to provide Pu239; by September 1954 about 17 kg had been extracted.

Postscript

Immediately after the war all the heavy water plants in the U.S. were shut down and the residues were transferred to the Trail plant for upgrading, which was, thereafter, operated under contract to the U.S. Atomic Energy Commission. In 1956 the contract was not renewed and the Trail heavy water output was offered to Atomic Energy of Canada Limited (AECL), the successor to the Atomic Energy Project of the National Research Council, since 1952. However, the offer was not taken up as cheaper sources appeared to be available from the U.S. AECL ran a small heavy water upgrader program at Chalk River and some of the secondary cells from the Trail plant were employed there as part of that program.

CMS amalgamated with Teck Corporation in July 2001 to become Teck-Cominco, which today produces zinc, lead, metallurgical coal, copper, gold and specialty metals. In 2005 the Trail heavy water exchange tower, long regarded as a safety hazard in some quarters, was demolished as part of a rehabilitation program. Today nothing remains at this historic site. A commemorative plaque is planned to be erected nearby at some future occasion. At the nearby Rossland Mining museum, a copper heavy water shipping container is on display in the Teck-Cominco wing.

Acknowledgments

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GENERAL news

Bruce looks forward to "new build"

On August 17, 2006, Bruce Power filed an application with the Canadian Nuclear Safety Commission (CNSC) to prepare a site for the potential construction of new reactors at its Bruce project. The type of plant has not been specified.

The company states that this is part of a long-term planning process that began in January of 2004.

Since then, Bruce Power has:

- Conducted a successful environmental assessment and launched a multi-billion dollar project to restart Units 1 and 2 and return 1,500 MW of electricity to Ontario by the end of the decade.
- Invested heavily in the long-term future of Bruce B by installing new turbine rotors and developing new fuelling techniques that have already resulted in power increases on two of the station's four units.
- Introduced a new fuel design at Bruce B that will enhance safety margins. Upon the successful conclusion of another environmental assessment, four new fuel bundles were loaded into Unit 7 last month and will remain in the reactor for approximately one year to test their design.

The overall plan considers refurbishing the four Bruce B reactors when needed and potentially building new ones. Much analysis work has been carried out over the last two years, the company point out, but there is a need to better define options and embark upon a more formal evaluation process. A detailed project description will be submitted to the CNSC this fall, formally launching an Environmental Assessment that will take approximately three years to complete.

In acknowledging the receipt of the application, the CNSC noted that an environmental assessment (EA) is a key pre-requisite for the licensing of a new nuclear reactor. The CNSC stated that it has extensive experience with EAs, and works closely with the Canadian Environmental Assessment Agency and other federal and provincial agencies to ensure an effective and efficient EA process that follows the requirements of the Canadian Environmental Assessment Act (CEAA).

The CNSC issued earlier this year a document entitled Licensing Process for New Nuclear Power Plants in Canada., which describes the various licensing steps.

CNSC president, Linda Keen, stated, "The CNSC has already been planning for this possibility through discussions with the CEA Agency. We are ready to move forward on this application – and any other applications that meet the criteria set out earlier this year – to the extent possible".

Bruce Power noted that it is very familiar with the Environmental Assessment process, having conducted successful studies in support of the Bruce A restarts and new fuel project.

An earlier aerial view of the Bruce Power site on the shore of Lake Huron with some of the towers of the former Heavy Water Plant still visible.

CNSC overturns staff order to shut down tritium plant

Following a "public proceeding" on August 28, 2006, on September 5 the Canadian Nuclear Safety Commission (CNSC) amended a "Designated Officer Order" that had been issued on August 15 to SRB Technologies (Canada) Incorporated (SRBT), to "cease and desist the processing and use of tritium" at its facility in Pembroke, Ontario.

The Order had been issued by Patsy Thompson, Director, Environmental Protection and Audit Division, as a Designated Officer under the Nuclear Safety and Control Act, after elevated concentrations of tritium had been discovered in groundwater on the plant property.

SRBT uses tritium to make unpowered illuminated signs such as for emergency exits.

The Commission determined "that the continued limited operation of the facility, under the restrictive operational parameters of its current licence and only during periods of no precipitation, will not exacerbate, in the time left to the licence, the risk to the environment."

SRBT's current operating licence expires on November 30, 2006.

The Commission stated that SRBT will need to demonstrate, at an upcoming public hearing, that it has the qualifications to carry out the activities associated with the operation of its processing facility. It also requested that SRBT submit a detailed report describing the specific actions and measures that will be taken to identify and contain all the sources of groundwater contamination, prevent or mitigate further direct contamination of the groundwater under the stacks, and remediate the contaminated groundwater.

Among the experts testifying on behalf of SRBT at the August 28 "Proceeding" was Richard Osborne, former Director of Health and Environmental Sciences at AECL's Chalk River Laboratory and a long-time member of committees of the International Radiological Protection Commission (ICRP). He stated that "the staff of SRBT are conscientiously applying ALARA" and that the continued operation of SRB wwould not pose an unreasonable risk to either the public or the environment.

The 194 page transcript of the August 28 proceeding is on the CNSC website. The Record of Proceedings, including Reasons for Decision, will be published on line later in September.

First steam generator for Bruce A Restart shipped

On August 3, 2006, the first of 16 steam generators destined for the Bruce A generating station was shipped from the shops of Babcock & Wilcox Canada, in Cambridge, Ontario, to the Bruce site.

Each of the four reactor units in Bruce A contains eight steam generators. Sixteen of the new vessels will be installed in Units 1 and 2 as part of the current restart project and there are plans to eventually replace the eight steam generators in Unit 4 as well.

Babcock & Wilcox Canada (BWC) has been contracted to manufacture the replacement steam generators, which each weigh about 100 tonnes and contain 4,800 corrosion-resistant tubes. Four steam generators will be attached to each of the two large steam drums in each unit, which have been retained.

BWC began work on these components in 2003. By the time the last one is complete in 2008, the project will have involved 900,000 hours of labour. The design and manufacturing for the Bruce Power components were done in Cambridge, with materials supplied from across the globe including Japan, the United States, Sweden, France and the Czech Republic.

Once onsite, SNC-Lavalin Nuclear will remove the old steam generators and install the new ones by precisely raising and lowering them through access holes in the roof using a heavy crane parked outside the powerhouse.

Staff of Babcock & Wilcox Canada pose with the first steam generator for Bruce A prior to the beginning of its journey from Cambridge to the Bruce site, August 3, 2006.

Two New Commissioners for CNSC

In June 2006 the government appointed two additional commissioners to the Canadian Nuclear Safety Commission. They are: Mr. André Harvey and Dr. Jean-Guy Paquet, both from Québec.

Mr. André Harvey

A native of Baie-Saint-Paul, Québec, Mr. Harvey received a B.Sc.A. in Civil Engineering from Université Laval, and an M.Sc.A in Water Management from the University of Waterloo in Ontario. Mr. Harvey was, for eight years, President of the Bureau d'audiences publiques sur l'environnement (BAPE), the Québec agency responsible for the public part of the environmental evaluation and assessment process. He held several positions within the Ministère des Richesses naturelles and the Ministère de l'Environnement, including, Director General of the Water Resources, Director General of the Environment and the Economy and Assistant Deputy Minister for Sustainable Development within the Ministère de l'Environnement.

Mr. Harvey has been a member of various organizations related to water and environment management. Notably, he was co-chairman of the Ottawa River Regulation Planning Committee, and under the auspices of the International Joint Commission, he was the Quebec representative on the International St Lawrence River Board of Control and a member of the Conseil d'étude sur le niveau d'eau des Grands Lacs. He was also member of the Board of Directors of Recyc-Québec and Collecte sélective Québec and a member of the Strategic Planning Committee of the Canadian Council of Ministers of the Environment.

Mr. Harvey received the 2005 Grand Prix d'excellence from the Ordre des ingénieurs du Québec – the highest honour for Québec engineers.

Dr. Jean-Guy Paquet

Dr. Paquet is a native of Montmagny, Québec. He received a B.Sc. in Engineering Physics from Université Laval, an M.Sc. in Aeronautics from the École nationale supérieure de l'aéronautique, Paris, and a Ph.D. in Electrical Engineering, also from Université Laval. Dr. Paquet is a former Vice-Dean of Science and Engineering, Vice-Rector and Rector at Université Laval.

Dr. Paquet is currently a member of numerous Boards including National Optics Institute (INO), International Development Research Centre, Industrial Alliance, General Insurance Company, Spectra Premium Industries Inc., Group Fontaine Inc, TELUS-QUEBEC Advisory Council, Canadian Advanced Technology Association and Canadian Academy of Engineering. In October 2001, he was appointed as Chairman of the Canadian Space Agency Advisory Council.

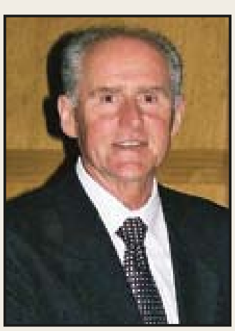
Dr. Paquet has received numerous honours, including: Grand Officier de l'Ordre national du Québec (2005), Gold Medal Award from the Canadian Council of Professional Engineers (2003); Grand Prix d'Excellence, Ordre des ingénieurs du Québec (1998), Fellow of the Royal Society of Canada (1978), and Companion of the Order of Canada (1994).

Dr. Paquet is a Fellow of the Royal Society of Canada and an honorary member of the Corporate Higher Education Forum and the Canadian Engineering Academy. He is the recipient of honorary degrees from McGill University, York University, University of Nova Scotia, University of Sherbrooke and University of Montreal.

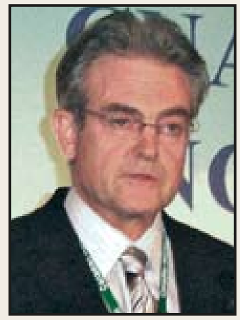
Changes at NWMO

At the end of June 2006 the Board of Directors of the Nuclear Waste Management Organization made a number of changes at the senior levels.

Elected as chair of the Board is Dr. Gary Kugler, who retired in 2004 as a vice-president of Atomic Energy of Canada Limited. He is also a member of the Board of Directors of Ontario Power Generation.



On assuming the chairmanship, Kugler said, "A priority task in this new position will be to continue the review already underway of future NWMO governance. Among other things we must consider Board membership and composition with a view to having a broader range of perspectives than industry executives." A former pilot in the Canadian Air Force, Gary Kugler holds a Bachelor of Science degree and a Ph.D. in nuclear physics from McMaster University.



Ken Nash has been appointed President and CEO of the organization. Mr. Nash is a founding director of the NWMO and most recently its Board Chair. He continues as Senior Vice President of Ontario Power Generation's Nuclear Waste Management Division. "I am committed to ensuring that the NWMO continues with its social, ethical and outreach program while also integrating the substantial expertise in technical R & D, finance, and international collaboration on waste management technologies developed by the nuclear industry over the last 20 years," he said on his appointment.

Elizabeth Dowdeswell, who served as President over the last three years, has agreed to continue to support the NWMO's Board of Directors as Special Advisor. Reporting directly to the Board of Directors, Ms. Dowdeswell will lead the development of a collaborative process for siting any facilities required by a government decision consistent with NWMO's visions and intentions set out in the Final Study issued in December 2005.

NWMO is still waiting for a formal response from the federal government to the recommendations in that Final Study report.

CNSC approves screening EA for Bruce refurbishment

On July 5, 2006 the Canadian Nuclear Safety Commission (CNSC) announced its conclusion that Bruce Power Inc.'s proposed project for the return to service of Units 1 and 2 and the refurbishment for life extension of the Bruce A Nuclear Generating Station (NGS), taking into account identified mitigation measures, is not likely to cause significant adverse environmental effects.

The proposed project also includes the activities associated with the potential use of low void reactivity fuel in all four units at Bruce A NGS.

The Commission's decision was based on its consideration of a screening environmental assessment of the project that was prepared in accordance with the requirements of the Canadian Environmental Assessment Act (CEAA). Further, with respect to the CEAA, the Commission decided not to refer the project to the federal Minister of the Environment for referral to a review panel or mediator.

The Commission therefore can proceed, under the Nuclear Safety and Control Act, with its consideration of a licence application from Bruce Power Inc. for the proposed project.

A Record of Proceedings including Reasons for Decision and transcripts of the hearing are available on the CNSC Web site at <www.nuclearsafety.gc.ca>.

CNSC Renews Chalk River Operating Licence

Following a two-day public hearing held on April 26 and June 28, 2006, the Canadian Nuclear Safety Commission (CNSC) has renewed, with a number of new conditions, the Nuclear Research and Test Establishment Operating Licence for Atomic Energy of Canada's (AECL) Chalk River Laboratories. The licence is valid until October 31, 2011.

In making its decision, the Commission requested that CNSC staff present a status report to the Commission on the performance of the Chalk River Laboratories during the first half of the licence term. The status report is to be presented at a public proceeding of the Commission.

During the public hearing, the Commission considered written submissions and oral presentations from AECL, CNSC staff and 37 intervenors. The Commission concluded that AECL is qualified to operate the facility and that it will make adequate provision for the protection of the environment, the health and safety of persons, and the maintenance of national security and measures required to implement international obligations to which Canada has agreed.

Transcripts of the hearing are available on the CNSC Web site at <www.nuclearsafety.gc.ca> or by contacting the CNSC.

(The Record of Decision, including the new conditions imposed, was not available at the time of writing.)

L-3 Communications MAPPS develops new LWR simulator

L-3 Communications MAPPS of Saint-Laurent, Quebec, has entered into a technical cooperation agreement with Southern California Edison (SCE) for support in benchmarking and validating L-3 MAPPS' new reactor core model for high-fidelity simulation of light water reactors (LWR). The new model, under development since last year, will be installed and validated on SCE's San Onofre Nuclear Generating Station (SONGS) simulator.

L-3 MAPPS is currently finalizing the development of an enhanced LWR core model based on the Nodal Expansion Method (NEM), called COMET™ Plus and an associated software tool – Chorus™ Plus – for adapting the core model to any LWR nuclear core. Chorus Plus will process any fuel data type regardless of the fuel manufacturer to generate the real-time reactor core model – COMET Plus.

L-3 MAPPS, a wholly owned subsidiary of L-3 Communications, was formerly part of CAE. The company has more than three decades of expertise in supplying plant computer systems for CANDU reactors. (with General News)

OPG to do EA for Pickering B refurbishment

Ontario Power Generation has announced that it will proceed with an environmental assessment as part of its business case study for a potential refurbishment and life extension of its Pickering B nuclear plant.

OPG has received confirmation from the Canadian Nuclear Safety Commission (CNSC) that a Federal Environmental Assessment (EA) is required prior to the refurbishment of Pickering B Nuclear Generating Station.

The Canadian Nuclear Safety Commission is expected to soon release draft guidelines that outline what is to be considered and included in the EA. The results of the EA will be documented in an EA Study Report and made available to the public. It is expected that an EA report could be ready in late 2007.

The EA for life extension of Pickering B will help identify any potentially significant environmental effects and mitigation measures that would be required. The EA will examine:

- the effects of the proposed project on all aspects of the natural and social environment, including cumulative effects;
- effects of potential accidents and malfunctions, and;
- effects of the environment on the project

OPG has initiated an assessment of the feasibility for refurbishing Pickering B to support its continued operation beyond 2015. The assessment will be a systematic, thorough review of the safety, environmental, financial and logistical aspects of refurbishment and continued operation. The review will be considered by OPGís management and Board of Directors, prior to making an investment decision.

Agreement to look at CANDU for oil sands

In August 2006, Atomic Energy of Canada Limited (AECL) signed an agreement with Energy Alberta Corporation (EAC) to develop opportunities for private sector financed CANDU plants to supply steam, hot water, electricity, electrolytic hydrogen and oxygen to oil sands operations in the Athabasca region of northern Alberta.

Natural gas is currently the main energy source used to generate steam for the in situ extraction process of bitumen, tarlike mixtures of hydrocarbons derived from petroleum from the oil sands and represents up to 65 per cent of total production costs. Natural gas prices have risen drastically in recent years and there are questions around long-term dedication of this supply source for bitumen extraction. The use of nuclear energy to displace the burning of natural gas and other hydrocarbons will reduce oil sands production costs and green house gas emissions. A 700-megawatt electrical power equivalent CANDU unit would save over three million tonnes of CO2 annually compared to a gas-fired plant

AECL officials were quoted as saying, "The agreement provides AECL with a strong local industry support and presence in Alberta that can bring to market CANDU technology, backed by long-term energy purchase agreements with oil and gas companies operating in the tar sands."

EAC is a recently formed company whose objective is to become a low cost energy provider to oil sands operators using CANDU nuclear technology. The company's founding partners are Wayne Henuset, a successful entrepreneur well known and respected in the Alberta business community, and Hank Swartout, founder, Chairman and Chief Executive Officer of Precision Drilling Corporation.

CNS news

Meet the President

As president of the Canadian Nuclear Society for 2006- 2007, **Daniel Allison (Dan) Meneley** brings a wealth of knowledge and a wide variety of experience to the position. He has held senior positions in design, defence, academia, research and international relations. Among his many awards he was presented the prestigious W. B. Lewis Medal in 1990.

Like several of his immediate predecessors in the Canadian nuclear program Dan hails from Saskatchewan, having been born in Maple Creek, on October 3, 1935 (in the middle of the great depression and the drought which affected that province the hardest). He was the second youngest of seven children. His father was a farmer and his mother a teacher, who taught him his first two years in a country school with a total of 13 pupils. After completing elementary and high school in Maple Creek he spent a year and a half doing irrigation and drainage surveying and subsequently qualified as a Saskatchewan Land Surveyor.

Dan enrolled in Civil Engineering at the University of Saskatchewan in 1954, graduating in 1958. Along the way he served as President of the Engineering Society. A year after graduating he married Mildred (Milli) Wiley. They had three sons and two daughters and now five grandchildren.

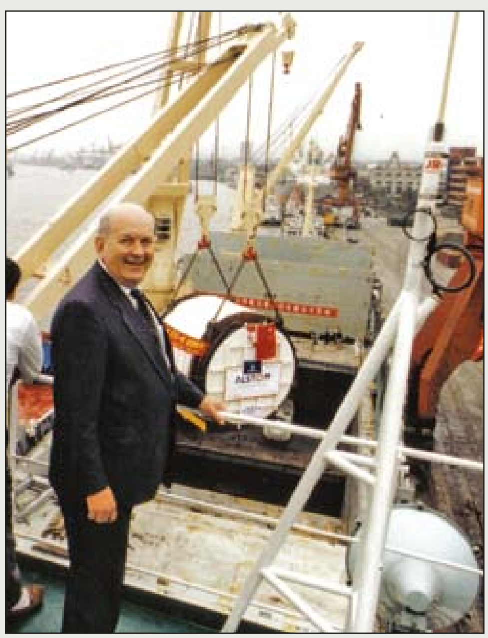
Introduced to nuclear engineering by then U. of S. Dean Arthur Porter he applied and won an Athlone Fellowship to study at the Imperial College of the University of London where he obtained a Ph.D. in 1963. He moved to Chicago for a one-year post-doctoral appointment at the Argonne National Laboratory. That translated into a nine year stay working on a number of experimental and theoretical research programs, including the conceptual design of a fast reactor, development of reactor physics and fuel management codes and involvement in the licensing of the Fast flux Test Facility.

When Dan and Milli decided that they wished to return to Canada, Ontario Hydro was expanding its then small nuclear group and Dan joined the Concept Department in April 1972. Over the next dozen years Dan was appointed to increasingly senior positions and was involved in many projects including: a safety reanalysis of Pickering A, licensing of Bruce A and Bruce B, the G16 pressure tube failure in Pickering A unit 2, and the conceptual design for Darlington. After the Three Mile Island accident of 1979 he led the OH team to review recommendations from organizations around the world and develop an action list for OH. From 1981 to 1984 he was Group Manager of the large Nuclear Group within OH's Design and Development Department and served as Secretary of the Nuclear Integrity Review Committee.

Over most of the years he was at Ontario Hydro, Dan also served as adjunct professor at McMaster University and participated in several annual reviews of the Applied Physics Division of Argonne National Laboratory.

Deciding he needed a change, in the spring of 1984 he accepted an offer to become a professor of nuclear engineering at the University of New Brunswick and hold the first NSERC Industrial Chair. The following year he was invited to join the first International Nuclear Safety Advisory Group of the International Atomic Energy Agency. The group's first report INSAG-1 was produced in the aftermath of the Chernobyl accident of 1986.

Back in Canada the Canadian Navy became interested in nuclear submarines and asked Dan to help in the evaluation. After his group had spent many hundreds of hours preparing a report the project was cancelled. His association with the Department of National Defence continued by serving (half time) as director general Nuclear Safety from March 1988 to December 1989.



Dan observing the unloading of the first Qinshan calandria in Shanghai, June 1999.

Just when the funding for the NSERC Chair was ending in 1991 Dan was invited to succeed Gordon Brooks as Chief Engineer at Atomic Energy of Canada Limited. From early 1993 to mid 1994 he took a leave of absence to teach at the Institute for Advanced Engineering in Seoul, Korea. In 1997 he moved to China to set up an AECL office in Shanghai. Not confined to the office, he gave short courses and seminars in various locations in China and organized courses at the Xian Jiatong University for the future operating staff of the CANDU units at Qinshan.

As well as being awarded the W. B.

Lewis Medal, Dan was named a Fellow of the American Nuclear Society in 1988 and of the Canadian Nuclear Society in 1998. He has been a member since 1996 of the International Nuclear Energy Academy (a group pf about 100 senior nuclear scientists and engineers) and was its chairman from 1998 to 2000.

He is the author or co-author of over 80 technical papers and 34 reports on a wide range of nuclear topics.

After retirement in late 2001, Dan and Milli moved to a home on Lower Buckhorn Lake, near Lindsay, Ontario. He continues to serve: as director (part-time) of the CANTEACH program sponsored by the CANDU Owners Group, as a member of the Defence Science Advisory Board (to which he was appointed in 1993), on the executive of a division of the American Nuclear Society, and to teach some courses at the University of Ontario Institute of Technology in Oshawa. Other than that, and his role as president of the CNS, Dan claims he and Milli live a quiet life!

Dan and Millie with grandchildren in 2003. Clockwise from Dan: Hannah, Daniel, Katie, Matthew, Julie, Lidia. Inset: step-grandsons David and Christopher

Dan and Millie at their wedding in 1959.

Dan in front of his new house at Lower Buckhorn Lake.

Historical Plaque for Douglas Point

On September 27, 2006, a historical plaque will be erected at the Bruce nuclear site to commemmorate the 40th anniversary of the start-up of the Douglas Point nuclear power plant in 1966. Douglas Point was a 200 Mwe prototype CANDU unit that paved the way for the larger Pickering and Bruce units which followed over the following decade.

Largely through the initiative of Jeremy Whitlock, the Canadian Nuclear Society successfully petitioned the Ontario Heritage Foundation to erect an official historical plaque.

Following are extracts from Jeremy Whitlock's official letter to the OHF proposing the plaque.

The Douglas Point nuclear generating station, located between Port Elgin and Kincardine on Lake Huron, represents a significant milestone in the technological and economic development of Ontario and Canada.

The facility, which operated for 17 years from 1968 to 1984 and is now dwarfed by the surrounding Bruce Power complex, was the prototype commercial-scale CANDU nuclear power plant. While the smaller "Nuclear Power Demonstration" (NPD) facility near Rolphton, Ont. (commemorated by an OHF plaque in 2002) represented the "test-of-concept" prototype that demonstrated technical feasibility, Douglas Point, ten times the power and a serious contributor to the Ontario electricity grid, demonstrated commercial operation and established the CANDU product. (Douglas Point was, in fact, the facility for which the name "CANDU" was coined, although this term was later applied generically to the product and the original CANDU became known simply by its geographic location, Douglas Point.)

Douglas Point's historical significance lies in the launching of not only Ontario's (and Canada's) large-scale nuclear power program, but also (and, remarkably, simultaneously) Canada's nuclear power export industry.

A "Nuclear Power Group", established in 1954 at the Chalk River Laboratories of AECL, forged the fundamental design of a prototype heavy-water-moderated, natural-uranium-fuelled power reactor that could compete with coal-fired plants. All but the latter of these goals were met by the 20 MW NPD plant, which started operation on the shore of the Ottawa River, 15 km upriver from Chalk River Laboratories, in 1962. The final goal, economic viability, required a commercial-scale power plant.

Federal Cabinet approval for Douglas Point was received in June 1959, and 2,300 acres on Lake Huron's shoreline were acquired for the project. Site clearing began in February 1960. The estimated project cost at this time was $81.5 million, with a target date of 1965 for full operation.

A number of "first-of-a-kind" issues delayed the construction of Douglas Point, and start-up ("first-criticality") was finally achieved on November 15, 1966. First generation of electricity came in January of 1967, and full commercial operation was declared on September 26, 1968.

In 1984 the decision was made to shut down Douglas Point permanently, rather than take on an enormous pressure-tube refurbishment project that was then required (the same fate would befall NPD three years later). The era of CANDU prototypes was over: industrial development had taken over, and resources were best spent elsewhere.

During its brief but important career Douglas Point contributed enormously to the learning curve of the Canadian nuclear industry, and to that of operators who went on to fill the control rooms at the Pickering, Bruce, Darlington, Gentilly, and Pt. Lepreau stations elsewhere in Canada. There were many "firsts" during Douglas Point's operation, one of the most significant being the world's first use of a digital computer program to control a power reactor.

Douglas Point now sits silent on the shoreline of Lake Huron, lost amongst the sprawling buildings of Bruce Power's 5,000 MW operation (alone supplying 1/5 of Ontario's needs), but symbolizing the genius, tenacity, and teamwork that got it all started 40 years ago.

Douglas Point plant at the left forefront. Bruce A is in the background. The towers are the former Heavy Water Plant now dismantled.

New members / Nouveaux membres

We would like to welcome the following new members, who have joined the CNS in the last few months.

Nous aimerions accueillir chaudement les nouveaux membres suivants, qui ont fait adhésion à la SNC ces derniers mois.

Alireza Abbasi, Ryerson University

Gewana Hanna Abdelmesih, Carleton University

Shiro Akahori, Hitachi Canada Ltd.

Michael A. Briggs, AECL

Don Chase, Scientech

Tom S. Chesworth, AECL

Gregory M.W. Fisher, SNC-Lavalin Nuclear

Ereen Abdou Hanna, Carleton University

Andrew Howlett

Roy Jakola, MDA

David Kurpjuweit, Ontario Power Generation

Brahms Martineau, University of Ottawa

John Naugler, AECL

Amir Abbas Sartipi, Ryerson University

Chris Selman

Brendan Simons, Stern Laboratories

Liqun Sun, NB Power Nuclear

Eugene van Heerden, Nuclear Safety Solutions

Michael J. Welland, Royal Military College of Canada

Saint John, N.B. venue for 2007 Conference

The CNS Council has endorsed the proposal to hold the 2007 CNS Annual Conference in Saint John, New Brunawick, June 3 to 6, 2007 and planning is well underway.

The venue will be the Saint John Hilton Hotel and Conference Centre. Atomic Energy of Canada Limited and NB Power will be the primary sponsors as the conference will highlight the refurbishment of the Point Lepreau generating station. Planning for that major undertaking is at an advanced stage with the refurbishment shutdown scheduled for early 2008.

A preliminary "Call for Papers" has been placed on the CNS website and posted in this issue of the CNS Bulletin. Chairman of the technical program is Krish Krishnan, e-mail: krishnanv@aecl.ca.

For more information or offers to help, contact conference chairman (and CNS 1st V.P.) Eric Williams at e-mail: canoe.about@bmts.com.

CNS Council creates "futures" committee

Following a proposal from CNS president Dan Meneley, the Council of the Society decided at its August 2006 meeting to create a Nuclear Futures Committee.

Noting that:

- nuclear technology must be prepared to provide an increasing fraction of the world's primary energy supply
- it will be necessary to build and operate nuclear power plants and associated facilities in rapidly increasing numbers
- at the same time, maintain high standards of reliability, safety and security

the Council established the "Nuclear Futures Committee" with a mandate of studying long-term energy needs and alternative technological means of meeting those needs. The Committee will be expected to recommend CNS programs resulting from its studies.

Membership of the committee is still to be determined. CNS members who would be interested in serving on it should contact Dan Meneley, e-mail: mmeneley@sympatico.ca

Shown are members of the "extended" CNS executive for 2006-2007. L to R: Ben Rouben; Adriaan Buijis; John Luxat; Denise Rouben; Dan Meneley (president); Eric Williams; Bob Hemmings; Jim Harvie; Ken Smith.

From the Canadian Nuclear Safety Commission

Regulatory Policy P-325 **Nuclear Emergency Management**

Provides guiding principles and directions for CNSC staff activities relating to nuclear emergency management.

Regulatory Standard S-296 **Environmental Protection Policies, Programs and Procedures at Class I Nuclear Facilities and Uranium Mines and Mills**

Sets out environmental protection policies, programs and procedures that licensees shall implement at Class I nuclear facilities and uranium mines and mills when required by the applicable licence or other legally enforceable instrument.

Regulatory Standard S-106 **Technical and Quality Assurance Requirements for Dosimetry Services**

Sets out the technical and quality assurance requirements that a licensed dosimetry service shall meet, when a condition of the applicable licence so requires.

Regulatory Guide G-296 **Developing Environmental Protection Policies, Programs and Procedures at Class I Nuclear Facilities and Uranium Mines and Mills**

Describes the elements of typical environmental protection policies, programs and procedures at Class I nuclear facilities and uranium mines and mills.

Regulatory Guide G-144 **Trip Parameter Acceptance Criteria for the Safety Analysis of CANDU Nuclear Power Plants**

Provides guidance to licensees who operate CANDU nuclear power plants regarding trip parameters that will preclude direct or consequential failures of reactor fuel or reactor pressure tubes.

Regulatory Guide G-306 **Severe Accident Management Programs for Nuclear Reactors**

Purpose is to help a person who applies for, or holds, a licence to construct or operate a nuclear reactor to develop and implement a "severe accident management (SAM) program" in accordance with the purpose of the *Nuclear Safety and Control Act*

From the International Atomic Energy Agency

Nuclear Security: Global Directions for the Future -
Proceedings of an international conference held in London, 16 – 18 March 2005

The conference considered the threat of malicious acts involving nuclear am other radioactive material; the experiences, achievements and shortcomings of national am international efforts to strengthen the prevention of, detection of and response to malicious act involving these materials; and the ways and means to achieve future improvements. These proceeding contain the opening and keynote addresses and the invited papers presented during the various topical and panel sessions. The conference generated an extensive exchange of information on key issue related to a number of aspects of nuclear security. The summaries of these discussions, as well as the findings, as presented by the President of the Conference are also included.

IAEA Nuclear Security Series No. 1
Technical and Functional Specifications for Border Monitoring Equipment

This publication provides a set of technical specifications that can be used in design testing, qualifying and purchasing border radiation monitoring equipment.

IAEA Nuclear security series No. 3
Monitoring for Radioactive Material in International Mail transported by Public Postal Operators

This report describes the control procedures and equipment that can be used to detect gamma and neutron radiation from radioactive material transported by public postal operators and private mail carriers. It also discusses countermeasures and defines a response procedure in case radioactive material is detected.

Website for all IAEA publications: www.iaea.org/books

31^{st} ANNUAL CNS/CNA STUDENT CONFERENCE
St. John Hilton, St. John, New Brunswick
2007 June 03 – 06

CALL FOR PAPERS

Again this year, the 31^{st} Annual CNS/CNA Student Conference will be embedded within the 28^{th} Annual CNS Conference. As usual, there will be a Best Paper competition for the students with awards at each level (undergraduate, Master's degree and Ph.D. levels).

STUENDT CONFERENCE TOPICS

The topics acceptable for Annual CNS/CNA Student Conference include any subject related to nuclear engineering, nuclear science and nuclear medicine.

CHOICE OF PAPER CATEGORIES

Student participants have two choices for the category of their presentations: either a fully refereed paper or a student (not refereed) presentation. In the first option, the paper may have as co-authors the student's supervisor(s) and other researchers who are not themselves students. The submission must then be made directly to the organizers of the CNS Annual Conference and the rules of the Annual Conference should be followed, including the 01 December 2006 deadline for notice of intent to present a paper (cf. CNS web site www.cns-snc.ca). The papers submitted in the first category will be included in the regular sessions of the CNS Annual Conference. Papers submitted for the student conference must be authored or co-authored by students only. To be considered as students, participants must be registered in a nuclear science or engineering program at a post secondary teaching institution at the time they submit their abstracts. Please indicate the level of the paper (Undergraduate, Master's or Ph.D.) and the names of the supervisor(s) and send the notification and short abstract by email to either:

Professor D. H. Lister dlister@unb.ca or
Professor W. G. Cook wcook@unb.ca

Submission Deadlines:

Submission of a short abstract (100-150 words):
05 January 2007

Notification of acceptance:
23 February 2007

Submission of conference papers:
06 April 2007

AWARDS FOR BEST PRESENTATIONS

Student presentations (non-refereed) will be assessed on the basis of technical and communicative merit by a committee of industry and academic representatives. Best papers awards will be given at each of the three levels Undergraduate, Master's and Ph.D. The exact nature of the awards will depend on the resources available at the Conference.

FINANCIAL ASSISTANCE

It is important that as many students as possible participate in the conference. For students presenting non-refereed papers within the Student Conference, conference registration fees will be waived and accommodation will be provided by the Conference. It is planned that a significant portion of the travel costs will be covered by the Conference and/or refunded to the student participants. Students who are not presenting papers at the Student Conference may register at the CNS Annual Conference at reduced rates.

28th Annual Conference of the Canadian Nuclear Society
and 31st Annual CNS/CNA Student Conference

"Embracing the Future:
Canada's Nuclear Renewal and Growth"

"Saisissons l'avenir: Renouvellement et
croissance du nucléaire au Canada"

2007 June 03-06
Saint John Hilton, Saint John, New Brunswick, Canada

Call for Technical Papers

The Canadian Nuclear Society's 28th Annual Conference will be held in Saint John, New Brunswick, Canada, 2007 June 03-06, at the Saint John Hilton.

The central objective of this conference is to provide a forum for exchange of views, ideas and information relating to application and advancement of nuclear science and technology, and energy-related issues in general.

- Invited speakers in Plenary sessions will address broad industrial and commercial developments in the field.
- University students in Student sessions will talk about their research and academic work.
- Speakers in ***technical sessions*** will present papers on industrial, research and other work in support of nuclear energy. ***This call for papers is to solicit technical session papers.***

Conference Website:
http://www.cns-snc.ca/conf2007.html

Deadlines

- **Receipt of Abstracts: 2006 December 01.**
- **Receipt of full papers: 2007 March 01.**
- **Notification of accepted paper: 2007 April 01.**

Paper abstracts (<100 words) should be submitted to the Conference Website. Please note that the abstract submission represents the author's commitment to submit a full paper on or before 2007 March 01 and, if the paper is accepted by the Conference Paper Review Committee, to present it at the Conference.

Guidelines for Full Papers

Papers should present facts that are new and significant, or represent a state-of-the-art review. They should include enough information for a clear presentation of the topic. Usually this can be achieved in 8-12 pages, including figures and tables. The use of 12-point Times New Roman font is preferred. Proper reference should be made to all closely related published information. The name(s), affiliation(s), and contact information of the author(s) should appear below the title of the paper.

NOTE

For a paper to appear in the Conference Proceedings, at least one of the authors must register for the Conference by the "early" registration date (2007 April 15).

Paper Submission Procedure

The required format of submission is electronic (Word 2000). Submissions should be made through the Conference Website by 2007 March 01.

Questions regarding papers and the technical program should be sent to:

V.S. (Krish) Krishnan
CNS 2007 Technical Committee Chair
e-mail: cns2007@aecl.ca
Tel: 905-823-9060, Ext. 4555

General questions regarding the Conference may be addressed to:

Denise Rouben, CNS Office Manager
e-mail: cns-snc@on.aibn.com
Tel: 416-977-7620

A Life Less Mindful

by Jeremy Whitlock

Bob was the kind of guy that always seemed in control of his life; he positively radiated energy and self-confidence.

"How on earth did he end up here?" I ask myself as I round a corner and the words loom over an archway: "Respite Home for the Incurably Empowered".

Later I ask the same question of the doctor as we stand before a wall of one-way glass. On the other side my friend sits apart from the other patients, pale and oblivious. His mouse hand is twitching. Drool runs from the corner of his mouth.

"Sad, really", says the doctor, rubbing his chin, "but a classic case. It all started with 200-channel cable TV. Guys like Bob jumped at the chance to program their own entertainment."

He draws a deep breath. "That was the start of mass empowerment."

I'm a bit confused, but the doctor continues.

"Around the same time PCs pervaded the workplace, but rather than making jobs easier they were seen as tools for downloading more work to the individual. All the time, it was called 'empowerment'.

"Guys like Bob didn't stand a chance of course. They eat that stuff up. And when the Internet came he never looked back. Internet..."

He says this last word through his teeth as he turns away.

"The choice, all the choice," I hear him say. "It always starts out looking like a vast improvement on things. We're in the Age of Choice. The Era of Empowerment."

I'm starting to figure it out. "He took on too much… choice?" I ask.

"He was sucked in!" the doctor whirls on me. "Bob did it all! At work he was doing all his own documents, graphics, slideshows, personnel forms, QA forms, project accounting forms. It's inverse-pyramid management.

"At home he was self-diagnosing with the medical websites, doing travel research online, booking flights, downloading music, reading ten different on-line newspapers, watching a hundred home videos a day on You-Tube, reading newsgroups, blogs, e-magazines."

I nod: "The global village".

"The global mall!" the doctor shoots back. He takes another breath and steps closer.

"Did you know he puts out his garbage in six different bins, according to category and sub-category of recycling, compost or trash? He goes to the grocery or hardware store and uses the self-checkout – why? Because he can. He hasn't let anyone pump his gas in twenty years. His movie theatre has 30 screens and he can buy his supper right in the lobby.

"When he relaxes in front of the TV he's now got 600 channels to choose from, in time-shifted digital satellite glory, and a PVR to let him watch twice as much in half the time."

The doctor pauses and brushes back a lock of grey hair. Behind him Bob is twitching.

"But the worst," he slowly adds, "is Wikipedia. A crack-house of empowerment. A self-declared cyber encyclopedia with millions of entries, that anyone can edit. Anyone at all…"

He looks over his shoulder at Bob, sadly.

"Bob edited. Bob corrected. He fixed mistakes, from simple grammar to outright lies. And as fast as he fixed things, spotty teenagers in Bangkok and Cleveland changed it all back.

"That's one of the biggest problems with mass empowerment," the doctor turns his gaze back to me, "The idiots have the keys to the bus."

I'm beginning to understand why I hadn't heard from Bob for months prior to his breakdown.

"Of course the Blackberry made this a 24/7 obsession", the doctor continues, "Sleep was not a priority. The crash came when the government distributed time-of-use hydro meters. Bob was up anyway so he spent any spare time he had calculating optimization routines for his appliance usage. Months later the government announced the result of this latest empowerment: electricity usage went up, because millions of customers suddenly found out just how cheap electricity was on a per-kWh basis.

"Bob ended up here about that time."

Driving home, through the arch and down the road, I wonder at poor Bob's fate: cautionary tale or the isolated collapse of an over-achieving personality? A familiar ringtone dashes my thoughts and nearly sends me off the road.

Of course I answer it.

2006

Oct. 15 - 20 — **15th Pacific Basin Nuclear Conference**
Sydney, Australia
website: www.pbnc2006.com
email: pbnc2006@tourhosts.com.au

Oct. 22 - 25 — **NEI International Uranium Fuel Seminar 2006**
Quebec City, Quebec
Contact: Linda Wells
Tel: 202-739-8091
email: ljw@nei.ogr

Nov. 12 - 16 — **ANS Winter Meeting**
Albuquerque, New Mexico
website: www.ans.org

Nov. 26 - 29 — **5th CNS International Steam Generator Conference**
Toronto, Ontario
website: www.cns-snc.ca

2007

Mar. 14 - 16 — **PHYTRA-1**
1st International Conference on Physics and Technology of Reactors and Applications
Marrakech, Morocco
email: erradi@hotmail.com

June 3 - 6 — **28th Annual CNS Conference & 31st CNS/CNA Student Conference**
Saint John, New Brunswick
website: www.cns-snc.ca

June 24 - 28 — **ANS Annual Meeting**
Boston, Mass
website: www.ans.org

Aug. 12 - 17 — **SMiRT 19**
19th Conference on Structural Mechanics in Reactor Technology
Toronto, Ontario
website: www.engr.ncsu.edu/smirt-19

Aug. 19 - 23 — **13th International Conference on Environmental Degradation of Materials in Nuclear Power Systems**
Whistler, BC
website: www.cns-snc.ca

Sept. 16 - 19 — **ANS Topical Meeting on: Decommissioning, Decontamination & Reutilization**
Chattanooga, TN
website: www.ans.org/meetings

Sept. 30 - Oct. 4 — **NURETH-12: 12th International Meeting on Nuclear Reactor Thermalhydraulics**
Pittsburgh, PA
website: www.ans.org/meetings

CANADIAN NUCLEAR ACHIEVEMENT AWARDS
CALL FOR 2007 NOMINATIONS

The Canadian Nuclear Society and the Canadian Nuclear Association jointly announce a call for nominations for the Canadian Nuclear Achievement Awards for 2007.

Details will be circulated in the form of a brochure with the next issue of the CNS Bulletin, and can also be found on the CNS web-site: www.cns-snc.ca

Although the deadline for all nominations is 2007 March 1 CNS members and others associated with the Canadian nuclear program are urged to consider colleagues who deserve to be recognized.

The Honours and Awards are in the following categories:

- W. B. LEWIS AWARD
- IAN MACRAE AWARD
- FELLOWS OF THE CANADIAN NUCLEAR SOCIETY
- INNOVATIVE ACHIEVEMENT AWARD
- OUTSTANDING CONTRIBUTION AWARD (individual and organization categories)
- JOHN S. HEWITT TEAM ACHIEVEMENT AWARD
- EDUCATION/COMMUNICATION AWARD
- CNS PRESIDENT'S AWARD
- R.E. JERVIS Awards (two awards, each with a $1,000 bursary)

For early information contact the chair of the CNA / CNS Honours and Awards Committee, Bob Hemmings, at e-mail: michelineandbob@sympatico.ca

2006-2007 CNS Council • Conseil de la SNC

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2006

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CNS WEB Page - Site internet de la SNC

For information on CNS activities and other links – Pour toutes informations sur les activités de la SNC

http://www.cns-snc.ca

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