CANADIAN NUCLEAR SOCIETY
Bulletin
DE LA SOCIÉTÉ NUCLÉAIRE CANADIENNE

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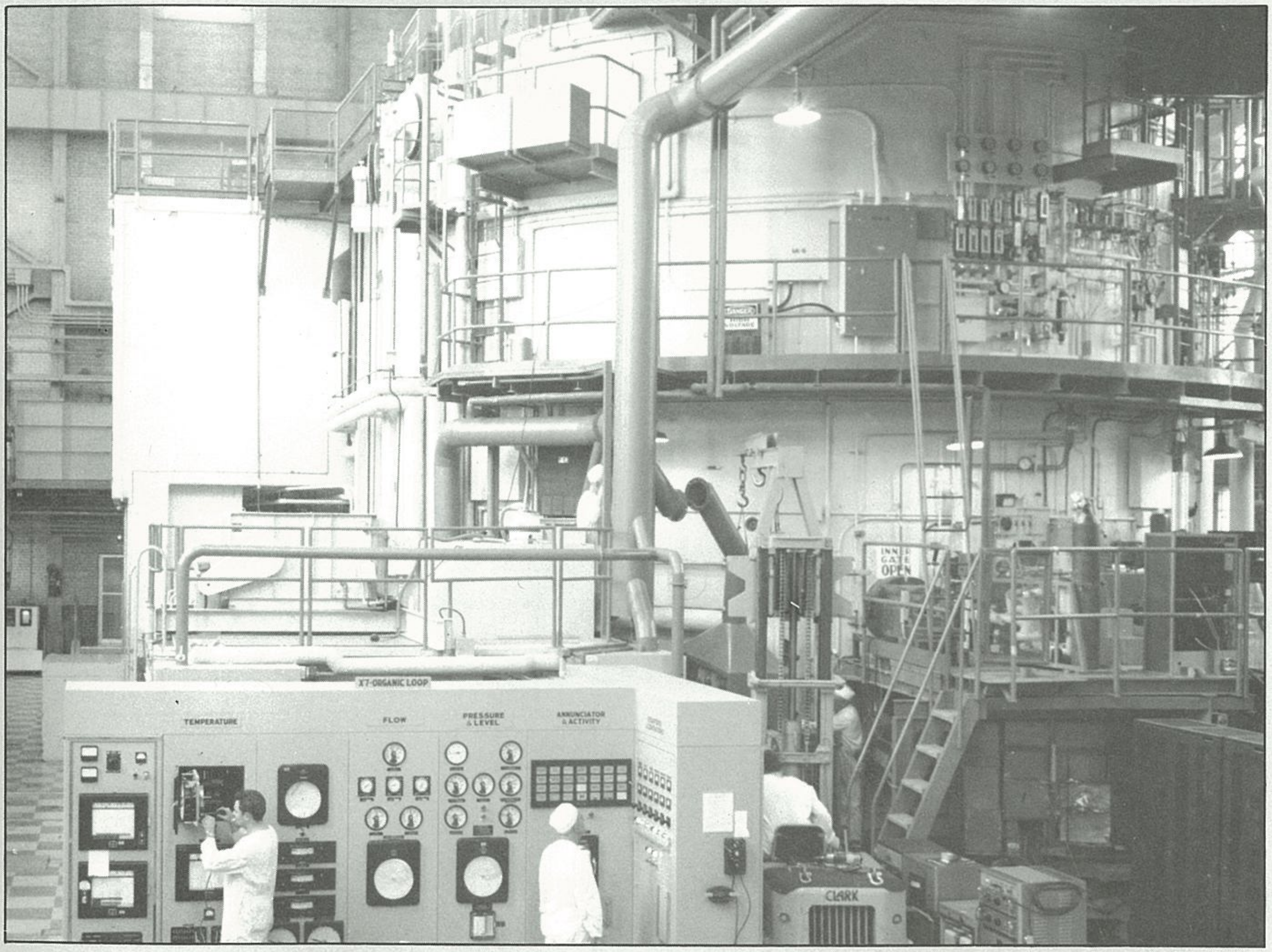

IN THIS ISSUE:

- Conference reports
  - CANDU Fuel
  - CANDU Maintenance
- Perceptions of Risk
- More history
  - NRX accident
  - CP-1
- RBMK safety

Contents

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Cover photo

The cover photograph is a view of the NRX reactor taken in the 1960's.

This and most of the material for the article on "The NRX Accident" was provided by the helpful people of the Public Affairs office, Chalk River Laboratories, AECL Research.

New associate

Ric Fluke, of Ontario Hydro, has agreed to become an associate editor of the CNS *Bulletin*. Based in Toronto, he will be keeping an eye of nuclear activities in that area. He can be reached at 416-592-4110.

Season's greetings

To all of our readers we extend the wish that 1993 will be a year of success and fulfillment.

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Bulletin

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Le Bulletin SNC est l'organe d'information de la Société Nucléaire Canadienne.

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

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

Editor / *Rédacteur*

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Editorials

The Ageing State of the Industry

The recent winter meeting of the American Nuclear Society in Chicago, celebrating the 50th anniversary of the first nuclear reactor, provided an insight into the current state of the nuclear industry in most of the world. This was particularly evident in the accompanying exhibition. Almost every exhibitor was offering services – inspection, analysis, decontamination, etc. The number of new reactor designs being offered could be counted on one hand, with digits left over.

A particular aspect of this situation which hits many of us who are facing the same problem in a personal way was the number of organizations concentrating on "ageing" (of reactors that is).

This direction of the industry was reflected in the CNS CANDU Maintenance conference held just a weak later in Toronto, which drew almost as many registrants as the CNA/CNS annual conference (and was more spirited).

The delegates to both gatherings also provided interesting evidence of the changed nature of the nuclear scene. A very large portion of those present displayed grey heads (or an absence of any head covering). In contrast, most of the team that joined with Fermi on that historic day in 1942 for the start-up of the first sustaining chain reaction were in their 20's or 30's. Similarly, as was noted at a recent retirement party, the small group that designed NPD, Canada's first nuclear power plant, were of the same age range. Today, would we trust any major project to anyone under forty?

Perhaps the ageing of its members mirrors the state of the nuclear industry. This is not necessarily all bad. Although age does bring decay, maturity implies wisdom. If the nuclear industry can mobilize the wisdom reflected in the experience of its members, perhaps it can overcome the ravages of age.

It pays to remember

As mentioned in the first issue this year, 1992 marks a number of nuclear anniversaries, such as:

- 60th of the discovery of neutrons, by Chadwick, 1932.
- 50th of the establishment of the Montreal Laboratory, 1942.
- 50th of the creation of the Manhattan Project, 1942.
- 50th of the start-up of the first reactor, December 2, 1942.
- 40th of the creation of AECL, 1952.
- 40th of the NRX accident, December 12, 1952.
- 30th of the start-up of NPD, April 1962.

Accounts of some of these events have been presented in this and previous issues of the CNS *Bulletin*, in the belief that there are lessons to be learned from history.

An old adage speaks of repeating history if we ignore it. Perhaps in some ways we should try to repeat history. A major message that comes through from all of the accounts of the early activities is one of determination, vision, and the willingness to make decisions and take actions.

Look at our own record. NRX was conceived (from elemental information), designed and built in just five years. The NPD team, despite having to change horses in mid-stream, did the same for our first nuclear power plant in less than seven years. Now, it takes that long to go through an environmental hearing!

Is it possible to regain some of that sense of purpose and those clear goals of the past?

In This Issue

A major Canadian historical event is highlighted in this issue – the accident to the NRX reactor on December 12, 1952. Another is included – the start-up of the world's first reactor in Chicago, December 2, 1942.

The start-up of CP-1 ushered in the era of nuclear reactors – first for plutonium production but soon after for research and the production of electricity. It was a symbol of the beginning of the world's nuclear programs.

Canada's only major nuclear accident caused great concern to those involved in or connected to the nuclear endeavour. NRX had started up just five years previously and AECL had been created just eight months earlier in April 1952. Although it was disastrous, almost destroying Canada's nuclear prize possession which had drawn world attention for its high flux and excellent experimental facilities, the accident had many salutary consequences. Staff learned that they could cope with a major breakdown and could deal with large, radioactive components. Of longer term importance, the event led to critical reviews of reactor control and reactor safety with the result that Canada is a leader in both areas.

In addition to these historical features there are reviews of two important recent CNS conferences – on CANDU fuel and CANDU maintenance. Both of these were very successful – attesting again to the organizing ability and dedication of many CNS members – and provided timely opportunities for specialists in these areas to share their knowledge and experience.

On a timely issue, there is a report on Canada's activities in eastern Europe towards improving the safety of the nuclear power plants in that area. And there are several other interesting articles – an eclectic selection.

Finally, as always, there is news of the Society and its members (beyond the two meetings referred to above).

Your comments, suggestions and contributions are always appreciated.

The NRX Accident

On a Friday December afternoon 40 years ago an event occurred which would have a significant effect on the Canadian nuclear program, especially on the development of reactor safety philosophy.

During preparation for reactivity measurements at low power, on 12 December 1952, "a complex concurrence of mechanical defects ... and operating errors ... resulted [in] a power surge in the NRX reactor."

This major accident, the most serious in the history of the Canadian nuclear program, resulted in melting of some of the uranium metal fuel and the release of an estimated 10,000 curies (about 4×10^8 MBq) of fission products into about 1,000,000 gallons (over 4,000,000 litres) of (light) water which was contained in the basement of the NRX reactor building.

The following accounts (and the quote above) are taken from the official report on the accident by Dr. W.B. Lewis, issued in 1953, and a 1955 paper by G.W. Hatfield.

(from "The Accident to the NRX Reactor on December 12, 1952" by W.B. Lewis, AECL-232).

"Overview

During preparation for reactivity measurements the reactor was unexpectedly found to be divergent, and at the same time there was some mechanical defect preventing shut-off rods from dropping in.

Even this would not have had serious results if a number of the uranium rods had not at the time a purposely reduced flow of cooling water. As the reactor was leveling off in power at about 17 megawatts, the cooling water of these rods boiled, thereby increasing the reactivity and the power. At the increased power, some of the aluminum sheathing the uranium melted. At least one rod blew itself apart, and molten uranium poured out from the core of the upper part. Some of the tubes retaining the heavy water ruptured. All the fluid systems of cooling water, air, heavy water, and helium were then in contact. The cooling water being under the highest pressure was forced in, displacing air and helium, and helped to bring the reactor below critical.

Meanwhile, however, the operators had been forced to their last resort; namely, to open valves which dumped the heavy water rapidly to storage tanks below. Within 60 sec the power was back to zero, but major problems of radioactive contamination had been set." [The shut-off rods were free falling, with air pressure used to provide an initial acceleration. They were raised by air pressure.]

"Reactor Loading and Intended Operation

The experiment on hand was a series of measurements of the reactor reactivity at low power. The main object was to compare the reactivity of long-irradiated rods with that of fresh rods. To avoid complications from dimensional changes in the water-cooling channels, it was necessary to blow the water out of some rods and substitute air cooling. At the time of the incident only one rod was air-cooled and that was a fresh unirradiated rod.

All enriched fuel rods, adjuster (cobalt load) rods, special assemblies, and isotope loads were out of the reactor except one thorium and uranium sample rod in an outer region.

A full complement of normal uranium rods was in position. Certain of these rods were to be moved between measurements and had only temporary cooling by means of hoses. Such cooling is adequate for low-power operations.

As the reactor had not been up to power for several days, transient poison had decayed, a necessary condition for the experiment.

Because of the experiments in hand, research physicists were present in the reactor control room, but the reactor was operated by the reactors branch personnel who alone have authority for this. The reactor loading to be used was recommended by the physicists and approved in writing by the reactors branch superintendent."

"Description of the Incident

The immediate chain of events which led to the accident began with an error by an operator in the basement who opened by mistake three or four bypass valves on the shut-off-rod air system, thereby causing three or more shut-off rods to rise when the reactor was shutdown. The supervisor at the control desk noticed this because the red lights came on. He phoned to the operator in the basement to stop and went down himself to investigate and rectify the situation, leaving his assistant at the control desk.

He recognized the operator's mistake and was horrified at the possible consequences if the operator had continued to open these wrong valves (actually he could not have opened all valves since some handles had been removed for safety). The supervisor rectified all valves and checked air pressures. He assumed that all shut-off rods would drop back into position, but, on account of unexplained mechanical defects, it is apparent from subsequent events and inspection that two or three did not drop back, although they slipped down sufficiently to clear all the red lights on the control desk.

The supervisor then phoned his assistant to press buttons 4 and 1. He had intended to say 4 and 3, but under normal circumstances 4 and 1 should have been safe (all the shut-off-rod red lights were out). His assistant therefore did so. Having to leave the phone to reach simultaneously with two hands the two buttons, he could not be recalled to correct the mistake. Button 3 having been pressed, the air pressure brought up by button 4 leaked away." [Button 4 charged air to the heads of the shut-off rod assemblies to provide the initial acceleration. Button 1 raised bank #1 of the shut-off rods. Button 2 raised the remainder of the shut-off rods. Button 3 increased temporarily the current in the solenoid magnets used to hold the shut-off rods in the up position.]

"Up in the control room it was soon evident when the first bank of shut-off rods was raised by button 1 that the reactor was above critical, which was of course a complete surprise.

It takes a few seconds for this to be apparent. There was surprise but no alarm for the next step would be to trip the reactor and thus drop back the shut-off rods. This the assistant did about 20 sec after pushing button 1. But two of the red lights stayed on, and in fact only one of the four rods of the first bank dropped back into the reactor and that over a period of about 1½ min. Even though, as it appeared, the air pressure had leaked from the header, all shut-off rods should have nevertheless dropped back under gravity.

The galvanometer spot indicated that the power level was still climbing up. The assistant telephoned the supervisor in the basement urging him to do something to the air pressure to get the rods down.

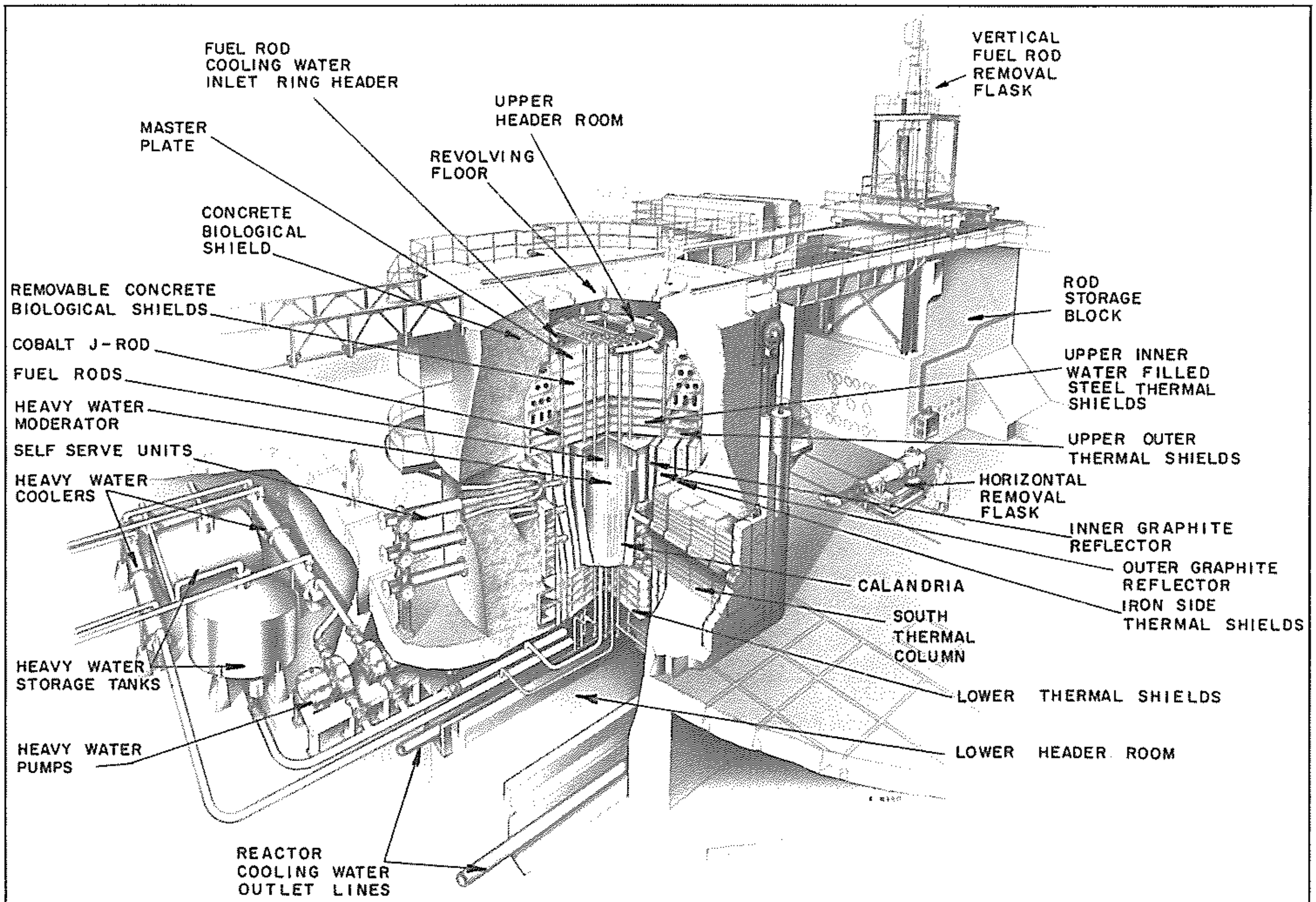
Others in the control room were worried: the physicists, the assistant superintendent of the reactors branch, and a junior supervisor. At least two thought of the last resort: namely, to 'dump the polymer.' All were familiar with the process as it had been done the previous day for experimental purposes. The assistant superintendent gave the word; one of the physicists was already reaching for the dump switch and beat the others to it.

However by this time the reactor power was up in the tens of megawatts, and the dumping took a few seconds to become effective. Then a fear arose that they might be dumping too fast as the helium pressure had dropped back sharply, and they envisaged danger of collapsing the calandria by vacuum. The assistant superintendent halted the dumping after about 1 min but after a little thought resumed it. However, in 10 to 30 sec after starting to dump, the instruments were back on scale, and the power rapidly dropped to zero. The assistant superintendent went to report to the superintendent, but the consequences were only beginning.

In the basement the door into the chamber under the reactor (the lower header room) was open. Through this an operator saw water gushing down, and immediately he called the supervisor. Their instant reaction was to suspect any water as being heavy water; therefore the supervisor and operator rushed in with a bucket and collected a sample, which was soon found to be light water but radioactive.

The assistant superintendent, returning to the control room, was met by an operator who reported a rumble and a spurt of water up through the top of the reactor.

Then the air activity began, and automatic radiation-level alarms sounded in the reactor building. A phone call to the control room from the adjoining chemical extraction plant reported atmospheric activity off-scale and requested the emergency stay-in procedure. The sirens for this were sounded. The radiation hazards control branch got busy reading instruments, making surveys, and collecting reports.



NRX REACTOR

ATOMIC ENERGY OF CANADA LIMITED - CHALK RIVER, ONTARIO

Some minutes later the activity inside buildings with forced ventilation was found higher than outside; therefore on the advice of the Biology and Radiation Hazards Control Director the Project Head gave the order for the plant evacuation procedure, and that went into effect.

Meanwhile in the reactor system not earlier than 30 sec before the dumping began, helium began to leak at a rate of 140 cu ft/min. After 3¼ min, by which time the reactor power had been down to a negligible level for 2 min, the reserve gasholder was almost empty. Then suddenly in less than 30 sec the 585 cu ft gasholder rose to its fullest extent. The change of direction of motion of the gasholder was so abrupt on the record and its motion so well-timed by pen marks at 15-sec intervals that it can be deduced with certainty that within a period of 15 sec the gasholder became connected presumably to a mass of gas at high enough pressure to give a large acceleration to the massive gasholder."

"The Power Surge

Although all relevant instruments went off scale, it proved possible to piece together data to construct reasonably well-timed curves of power and reactivity.

Before the first bank of shut-off rods was raised the reactor was more reactive than supposed owing to a number of shut-off rods not being down. This unsuspected extra reactivity was about 10 mk. Raising the first bank made the reactor overcritical by about 6 mk, and it diverged with a doubling time of about 2 sec, reaching a power of the order of 100 kw. At this point the reactor trip circuit opened, but only one shut-off rod fell slowly in. The reactor continued to diverge but at a rate decreasing with time in such a way as to suggest that it would have leveled off at about 20 megawatts.

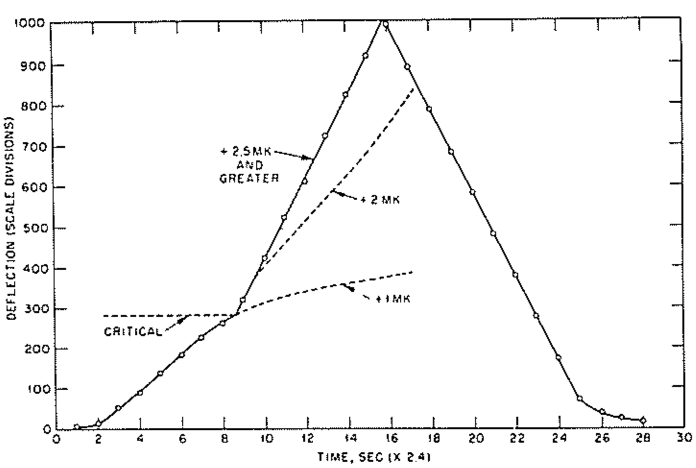


Figure 1: Expanded trace of power recorder during the power surge with transients from simulator superposed. (Time scale is in units of 2.4 sec., the interval between successive balancings.) ——, NRX transient. - - -, reactor simulator transient.

At 17 megawatts on this scale boiling is presumed to have occurred in some of the temporarily cooled rods, expelling light water from the reactor and increasing the reactivity by at least 2 mk. The reactor continued to diverge for a period of 10 to 15 sec and reached a power between 60 and 90 megawatts when it was checked by opening the heavy-water dump valves and also possibly by ingress of light water through ruptures in the cooling-water tubes. Tentatively the power surge is taken as 4000 megawatt-sec."

(from "A Reactor Emergency – with Resulting Improvements" by G. W. Hatfield, AECL-164).

"It was not considered safe to shut off the flow of cooling water as the condition of the uranium was not known. The main concern was the fact that some of this uranium was highly irradiated and, if this uranium were not cooled, it would heat up to the point where the metal would oxidize rapidly and even catch fire. Therefore, as the first precaution, the cooling water to all the rods in the reactor was decreased to a minimum by gradually throttling the flow of water through the valves heading to the main header. In this manner the flooding of the basement was decreased from 300 to 60 gpm. This was followed later with shutting off the cooling water to the rods which were not ruptured after installing special headers. Here, needle valves were used to control the flow at the top and bottom of each ruptured rod. After this installation was completed the leak to the basement was decreased to 14 gpm.

At the same time, while we were endeavouring to decrease the flooding below the reactor, the active water which already had collected in the basement was being pumped to large storage tanks outside the main building and these tanks were rapidly becoming filled to capacity. A decision was made 5 days after the accident to pump this active water out to the disposal area where the soil was a mixture of sand and clay. In zero weather a pipe line 1¼ miles long with the necessary pumping facilities was installed in the next 5-day period. Approximately 1,000,000 gal of active water containing 10,000 curies of long-lived fission products were pumped through this pipe line to the disposal area. A check was kept on the activity in the water draining from the disposal area and no detectable activity has been found even in the creek draining this area to a small lake.

"Dismantling the Reactor

It is difficult to describe the multitude of problems associated with radioactivity with which we were faced during the next 8-month period when dismantling the reactor. These problems included the design and fabrication of many special tools for use by remote control for cutting and removing the ruptured rods out of the reactor as well as the removal of the stainless-steel water headers and valves below the reactor which were badly contaminated, and the decontamination of thousands of square feet of concrete throughout the reactor building.

Removing the Aluminum Calandria. The procedure used for removing the aluminum calandria from the reactor will be described. This calandria is probably the largest radioactive source that has been handled to date.

Owing to this high level of radioactivity, all operations had to be controlled remotely.

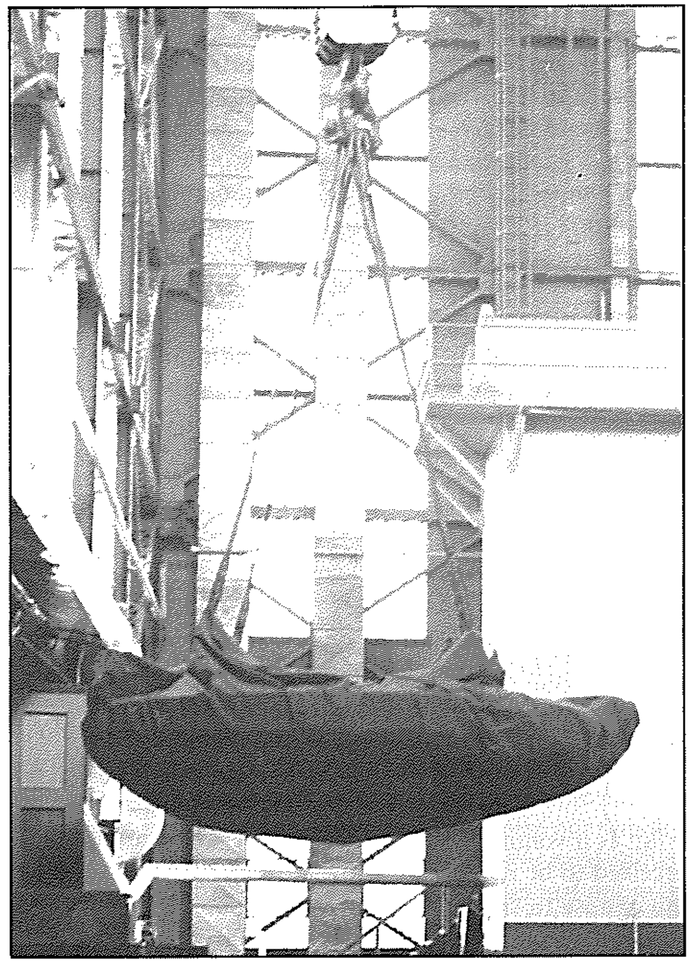
A lifting jig was first lowered down on top of the calandria. This jig had dogs hanging below, designed in such a way that when the dogs entered the holes through the calandria tube sheet, they slipped outward hooking onto the underside of the sheet when a lifting strain was applied to the jig. The overhead crane hook was lowered and engaged by remote control to the hook on the lifting jig. The calandria was then raised out of the hole and, with the use of long ropes as guides, it was moved across the pile by the crane and lowered into a canvas bag which was attached to a skid turned up on one end against the side of the reactor.

The skid was then lowered into a horizontal position on the floor of the reactor building by slackening off on a yoke which was attached from the outer face of the skid to the inner face of the reactor and thence out to a bulldozer which acted as a winch. After the skid was in a horizontal position on the floor, the pin was withdrawn from the outer end of the skid by means of a long rope attached. This released the skid from the yoke.

The skid was then towed out of the reactor building, with all remaining ropes attached, with the use of a grader, through the plant proper to the disposal area about 1½ miles away.

Radiation Measurements. Radiation measurements on this tank indicated 20 roentgens per hr in contact with the top tube sheet, 100 roentgens per hr in contact with the side of the tank, and 300 roentgens per hr in contact with the bottom tube sheet.

Reconstructing the Reactor. On reconstructing the reactor all of the equipment removed was decontaminated and used over again, such as shields, water headers, pipes, valves, instruments, and so on, with the exception of the aluminum tank and one steel shield immediately above the tank which were purposely damaged beyond repair in order to simplify the removal of the ruptured rods. These two pieces of equipment were replaced by new equipment."



Carefully swathed to prevent the spread of radioactive contamination the thermal shield is lowered onto a skid during the dismantling of the NRX reactor following the accident of 12 December 1952.

How Others Saw It

Although there was fairly widespread media reporting of the NRX accident it was relatively subdued, especially in comparison to more recent events such as TMI and Chernobyl. This was partially due to the secrecy that still surrounded the Chalk River project at the time and partially to the different social environment of the period. The federal minister responsible for atomic energy program, C.D. Howe, announced that the reactor had suffered "a pin hole leak" which, apparently, was accepted by the press, at least initially.

Later there were some lurid accounts. Almost a year later the American magazine, *Popular Science*, ran an article about the removal of the calandria under the title, "An Atomic Dragon's Eerie Funeral." Following are some excerpts from that story.

"This is the story of a funeral – the strangest funeral in the history of man. The coffin was a huge canvas bag, the grave a great hole and the mourners atomic scientists.

"The corpse was the [NRX] calandria – the largest and most dangerous radioactive object that has ever been handled.

[After the immediate handling of the accident] "the next step would be the dramatic operation of removing the calandria. The plan – an overhead crane would lift the tank (10 ft. high, 8 ft. dia.) out of the 35 foot-high reactor structure. Then the tank would be dropped into a huge canvas bag on a cradle. The cradle would be lowered to horizontal, onto skids, and towed away to a burial ground outside the [inner] plant.

"A long whistle blast warned that the funeral procession was underway. In buildings along the way pens of radiation monitoring instruments went off the charts.

"The [burial] ground will not go unvisited – but so formidable is this atomic dragon, even in death, that it will be perilous to approach for some time to come."

Bibliography

For those who would like to read more about the NRX accident, following are some relevant AECL reports:

AECL-232 The Accident to the NRX Reactor on December 12, 1952
W.B. Lewis

AECL-233 Accident to the NRX Reactor, Part II
D.G. Hurst

AECL-164 A Reactor Emergency – with resulting improvements
G.W. Hatfield

AECL-83 Reconstruction of the NRX Reactor
J.L. Gray

AECL-590 An Appreciation of the Problem of Shut Off Rods with special reference to the NRX Reactor
W.B. Lewis, A.G. Ward

AECL-1877 Fission Product Release from the NRX 1952 Accident
W.J. Edwards

Perceptions of Risk

Roxanne Summers

***Ed. Note:** The following is extracted from a luncheon address by Roxanne Summers, the new CNA Vice-President of Communications, to the CNS CANDU Maintenance Conference, 23 November 1992, in Toronto.*

Roxanne Summers

My topic today is, in fact, RISK. Why is it that the public views nuclear power as, at best, a necessary evil, and, at worst, a symbol of certain doom?

Why do "they" perceive it as a high risk and "we" see it as low? And why should it matter? It matters because this industry requires public and political support to remain viable. I don't think I need to belabour that point.

Take the first criterion of risk, and the most important by far: Is it voluntary? If it is imposed by someone else, it is perceived to be riskier. We know a dozen examples: people who choose to smoke, or to drive without seat belts, or to jump out of airplanes. If we were *required* to do some of these things, we would resist automatically. But because we choose to expose ourselves to the danger, we think we have lessened the risk. Thus, those of us who voluntarily work with radiation feel less at risk than those who may be exposed to it involuntarily.

If the lights went out without nuclear power you would get stronger support.

Closely related to the voluntary aspect is our ability to control risk, and there again, those of us who work with it do have some control over it. The public tries to gain some control, mostly by opposing its use.

All sources of electricity are imposed by utilities or governments or some other "big brother," so nuclear power is neither voluntary nor controlled by the public.

Having someone to blame is important. Look at the difference in the public's reaction to radon, compared to nuclear power or waste. People are much more likely to be affected by radon than by a nuclear facility. Yet, partly because it came from "God," or "Mother Earth," or because it is "natural" and not "man-made," the response to it has been quite reasonable – the fear has been tempered by the knowledge that, since man didn't create it, we can't do much about it anyway.

Fear is heightened by something you cannot see, hear, feel, smell or taste. Ghosts are a good example. In nuclear facilities, we have alarms to warn us. The general public has no such alarms, and no defence against radioactive air or water, even if there were alarms.

As scientists we trust the technology that protects us, but the public does not. Why? Because the public doesn't understand radiation. Children don't learn about it in school, their parents don't know about it, and you have to be practically at the university level before you might (if you studied the right subject) find out about it. We are trying to change that, but teachers resist teaching something *they* haven't studied. It's a vicious circle.

Another cause of fear is something that can cause a lot of deaths, especially delayed deaths. A car accident, and boom – you know you've been hit and you're either dead or you're not. But exposure to radiation ... who knows if you were, who knows how much, who knows what the effect will be, and how long before you die from it. For the public, if one accident can harm a lot of people, it is scary, even if it only has a one in a million chance of happening – scarier than if it could harm ten times more people in separate accidents. Furthermore, if children can be exposed, the fear is greater. We may take a chance ourselves but refuse to risk our children. And this doesn't take into account the public image of a nuclear bomb, an image that is created just by the use of the word "nuclear."

The first criterion of risk – is it voluntary?

When we *do* encounter risk, we look for a big benefit to offset it. Here, and in many countries, nuclear power competes with other energy sources, and the lights go on, whether we use oil, coal or gas, not to mention hydro. If the lights went out without nuclear power ... you would get stronger support. We are seeing this in the former Soviet Union and Sweden, as well as in Japan, Taiwan and Korea.

And last on my list, but scarcely least, let me say a word about women. We know that women are more opposed to nuclear power than men. Why? Look around you. How many women are here? That's one reason! There are almost no women in this industry. Women know that you guys cannot be trusted to worry about food, children, health, future generations – all that "soft" stuff – because you are more interested in high tech gadgets, cars and machines, computers, sports. Women *do* think this way. We would be reassured if we knew women were nuclear plant managers, operators, safety inspectors – but by and large, they are not.

Some of these problems can't be changed. Radiation is always going to seem invisible, "man-made," and potentially harmful to large numbers of people, if they are exposed to it. But let's see what happens when we do change some of these perceptions.

Women know that guys cannot be trusted.

Let's take France, where I lived for 16 years. Let's take the country of Madame Curie. Every school child studies her and is proud of her discovery (AND she was a woman! And her daughter was also a famous nuclear physicist!). That's how French children learn about radiation at a young age.

Let's take the word "nuclear." France is probably the only country in the world that thinks "nuclear" is a good word. Nuclear weapons gave the French independence from NATO; nuclear power has given them a source of energy independent from the Middle East and other undependable suppliers. And, as you know, I've just just used, twice, the most important word in the French language – independence!

Since the French don't have any other source of energy, they see a large benefit. And because they learn about it in school, they are less afraid of this invisible ghost. It is familiar, it is important.

I haven't mentioned the media, because that is a subject in itself. But in North America, public opinion is shaped by the media, and in order to shape that opinion, our industry must go out and *advocate* their position. We have been far too *reactive*. The moment we do this, we are dealing with risk – the risk of being misunderstood, taken out of context. We still haven't learned to talk to the media in their language. They have to report on many subjects they didn't study in school, and we have to make it easier for them to do it right.

We haven't learned to talk to the media in their language.

Now, I would like to mention just a few of the ideas being tried in this country and others. Let me tell you about the Japanese. They had no real worry about public acceptance until two or three years ago. But when opposition arose, they immediately tackled it – with a major commitment of resources. Their budget for 1992, just for public information, for the two government agencies alone, was 52.5 million U.S. dollars! The Japanese will mail a compact radiation measuring device to anyone in their country for a month, free of charge. This helps make radiation more familiar, more understandable.

The Japanese are also building a power plant with glass corridors running all through it, so that large numbers of people can see the control room, the fuel handling area, the turbine building, all without disturbing the operations. We all know that every person who visits a nuclear power plant leaves with a more positive attitude. So they are going to make sure that everybody does visit one.

You may have heard how the British turned their Sellafield nuclear centre into the largest tourist attraction in England, just by making it inviting and accessible. In fact, they got so many tourists, they had to build a large visitor centre!

In Canada, we are trying to increase the understanding of teachers. For example, at our CNA meetings twice a year, we have a special program for teachers that includes a tour of a nuclear facility. We wish we had the funds to expand this program.

We need to encourage more women to work in this industry, and in science and technology, in general. We need to make sure libraries have a balanced array of information. We need to make sure our neighbours, and even our families, understand the benefits of nuclear energy. We need to have information centres in the middle of cities, not just out in the small towns where nuclear plants are located. And exhibits for schools that are interesting as well as informative.

I could give many more examples. They all take time, effort and resources. Most of all, they take a different attitude on the part of the industry. But they work. If you'd like to help, give us a call.

Pickering 'A' Retubing Completed

(Taken from a statement issued in November 1992 by the Pickering Retubing Project team.)

The Fall of 1992 saw the completion of one of the most difficult tasks undertaken at Ontario Hydro's Pickering Nuclear Generating Station – the replacement of the fuel channels of the four Pickering "A" CANDU Reactors.

Retubing was originally scheduled to start in August 1989, but in August 1983 pressure tube G16 in Unit 2 ruptured. This resulted in heat transport system water escaping into the annulus gas system, causing pressure build-up which ruptured the bellows, spilling radioactive heavy water onto the vault floor. This failure initiated the shutdown of Units 1 & 2, and brought forward the preparations for "Retubing."

Retubing of Unit 1 & 2 began in October 1984 and was completed in July 1987. This was the first time that a project of this magnitude had been attempted and successfully completed on a previously operating nuclear unit.

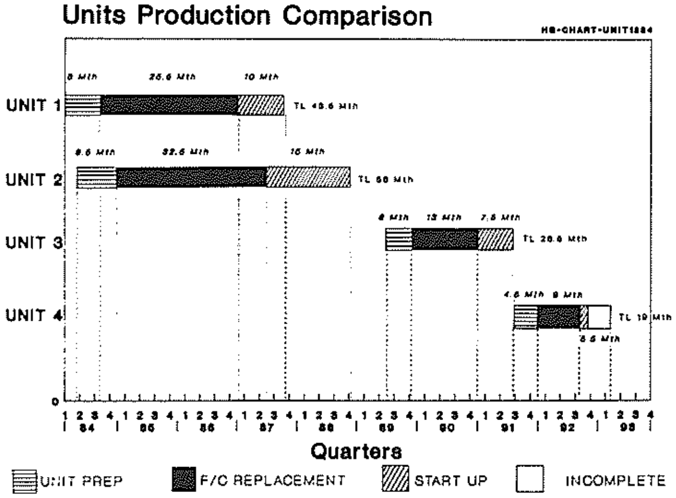
The task, although simple in concept, was complicated by the work done in a radioactive environment. The people at the face of the reactor had to work from inside a shielded cabinet wearing protective suits supplied with breathing air. In addition, communication headsets and a variety of radiation monitoring equipment were required. They were directed in their tasks by colleagues monitoring them remotely from an adjacent control room. The simplest tasks became difficult because of the unusual conditions in the vault.

The Retubing Program for Units 3 & 4 differed in many ways from the Units 1 & 2 Program. In P1 and P2 the west endfittings and the pressure tubes were removed, while the east endfittings were saved. Saving the east endfittings was accomplished by shock heating the rolled joint to allow removal of the pressure tube. These operations were very time consuming, resulting in high radiation dose to the workers. In Units 3 & 4 both endfittings and pressure tubes were removed, eliminating the requirement of shock-heating.

The overall time for the fuel channel replacement of Unit 4 will be 19 months compared to 56 months for Unit 2.

Pickering "A" NGS" Retubing

Units Production Comparison



Purple Passage

I asked, "Has someone broken in?"
He checked, and said he couldn't see
That there was anything amiss –
No pilfered cash; no stout, whisky
Or rum purloined from cupboard shelves.
We still had grandpa's Wells (H.G.),
But Terror! Horror! Shock! We found
Someone had taken Fifty-Three!

Look here! The table's organised,
Laid out the way it ought to be –
No problem seeing trends in charge,
In valence or affinity.
Both Eighty-Five and Thirty-Five
Are still in place. At wind and lee
Sit Fifty-Two and Fifty-Four –
The skunk Te; the ghost Xe.

Mind you, some doubt was raised back then,
At Harrisburg, Mile Island (Three);
The codes all told us it was there,
(And codes don't lie to me or thee).
We scoured the place, in water, air,
In soil, in house and factory.
We checked the lot. We checked again.
There wasn't any Fifty-Three.

Ten years of struggle passed. We groaned
And sweated with pugnacity.
Gray, green and greasy were our thoughts,
For fault had turned to fever tree.
The Mother of all Codes we wrote;
With test rigs huge, with spending free
We put Ma Nature on the rack –
She laughed at us, and said "Maybe!"

So! Is it all a hoax? Is this
The Piltdown Man of chemistry?
Or was the stuff mislaid? Consumed?
On Jenkins' Ear or Wounded Knee?
Old Wilkinson's gone mad with grief,
And Cotton's turned to gin, you see.
No help from them. Poor Dushman's gone.
No answer from Whiteshell (R.E.).

Chalk's deserted. Argonne's fled.
And Livermore has proved to be
Completely hopeless. Harwell waits
Approval from the CEC.
I hear that there's a massive change
Of knickers at AECB –
But please, you must excuse me now,
It's time to draft a new CV.

Keith Weaver

***Ed. Note:** Keith Weaver, who is involved in fission product studies and is a former co-editor of the CNS* Bulletin, *says a clue to the numerical references can be found in the periodic table.*

A Plan for Low and Intermediate Level Waste

Ontario Hydro's Commitment to Low & Intermediate Level Waste Management is a First for Canada

Peter Stevens-Guille

In the summer of 1992 the Board of Directors of Ontario Hydro approved a comprehensive plan for the utility's low and intermediate level waste and its ultimate disposal. This plan, some two years in the making, is now published and available to government, industry and interested members of the public.

This is a first for Canada. Much as we compare ourselves with the G-7 group of countries on economic and technical matters, Canada has lagged behind in the disposal of nuclear waste. Many major countries with nuclear power have been disposing of their nuclear waste for decades. Even small countries with small nuclear programs are far advanced. Finland, for instance, opened a repository for waste disposal at the 2-unit Okiluto station in 1992.

Dimensions of Problem

- At present, no long term solution
- Many waste streams
- Three categories of waste by radioactive hazard
- Several technologies exist for management
- Several storage sites exist
- Timescales of waste arisings extend to 2070
- 97% of waste volume has 4% of radioactivity.

What Hydro has been Doing for the Past 30 Years

Since 1962, when NPD started operation, Ontario Hydro has been generating low and intermediate level waste. The low level waste consists of items such as cleaning materials, metal and plastics. Intermediate level waste is usually composed of chemicals known as resins used to purify coolant streams. Procedures have been in place since these early days to collect the waste, process it in some cases, and store it safely.

Wastes are stored at the Radioactive Waste Management Operations Site (RWOS) at the Bruce Nuclear Power Development. It is impressive to see this site which covers a mere three Ha (about six acres) yet it contains over 90% of all the waste generated since the start of the nuclear program in Ontario.

Present waste management practices cover production, transportation, treatment and storage. In a typical year 7000 m^3 (equivalent to 30 railway cars of waste) is trucked to the RWOS. Over 97% by volume of the waste belongs to the least radioactive category, and much of that volume is a candidate for burning (incineration), compaction (volume reduction), or both. At present, receipts exceed the capacity for these actions, so some of the least radioactive waste is stored in warehouses, while the more radioactive materials are stored in a variety of in-ground steel and concrete containers.

What the Plan Commits Ontario Hydro to Do in the Future

The Plan continues the current practices and adds a program for the ultimate disposal of the waste.

Production

Production of waste in Ontario Hydro on a reactor basis is not low by world standards. So it was recognized that the principle of minimizing production at source by preventing materials from unnecessarily becoming radioactive should be applied. Targets call for a 25% volume reduction by 1995 and a total reduction of 50% by the year 2000. This is to be accomplished by:

- Material control procedures to prevent materials from unnecessarily entering radioactive areas,
- Enhanced waste monitoring to reduce inclusion of non radioactive waste,
- Improvements in handling
- Employee awareness and training.

Transportation

In a typical year over 1000 truck shipments are made by Ontario Hydro, covering 300,000 km. Only three minor accidents have occurred in 30 years; none resulted in the release of radioactive material. The Plan calls for continued use of truck transport to the central RWOS site.

Treatment & Storage

Present incineration and compaction facilities are aging. New equipment is being investigated to reduce volumes by up to 90%. It will be designed to meet Atomic Energy Control Board (AECB) and provincial regulations for safety and the environment. Appropriate approvals and public input will be sought.

Synopsis of Plan

- Minimize waste produced at source
- Continue to store majority of waste at RWOS-2; continue to store some waste at stations
- Use road transportation; study & develop transportation systems for the future
- Enhance centralization volume reduction capability
- Develop a disposal program
- Continue to participate in waste management activities with public, citizen liaison committees, elected officials.

Conditioning is a necessary step in the management of certain types of waste to render it stable for storage or disposal by processing it with cement, bitumen or specially developed materials. Ontario Hydro will develop and use conditioning technology for storage and disposal.

Hydro stores most of the waste at the RWOS. The volume stored since the start of the nuclear program in Ontario is 30,000 m³. This can be compared, for instance, with over 1.5 million m³ in France. There is sufficient space at RWOS to store the waste predicted for many years to come.

Disposal

In the long term disposal of waste is a necessary step. The AECB has established regulatory requirements which demand that in the long term a waste disposal site would not require human custodianship. The time required to select a site, obtain public input and government approval, and build facilities is 15 to 20 years. Ontario Hydro plans for an in-service date of 2015 for a single site that is anticipated will meet the requirements of the utility but is also considering a shared site with government or industry.

In 1993 and subsequent years a charge for disposal of low and intermediate waste will form a small part of electricity bills to collect funds for this program. The eventual costs of disposal for the current nuclear program will be of the order of $500 million.

Public Involvement and the Approvals Process

One of Hydro's goals is to "... actively seek to work individuals, organizations and communities who have a stake in radioactive materials management". Before this Plan was finalized, it was discussed with the public in focus groups sessions in six centres in Ontario. The resulting feedback was incorporated in the Plan. In addition the Plan was reviewed by government, an overseas waste management company and Hydro's own external environmental panel.

Copies of this Plan are being sent to several hundred interested individuals, groups and agencies. Copies will be available at all the nuclear information centres. At a later stage when decisions on disposal methods and siting arise, the public will be involved in the decision making process by Hydro's community involvement program and via public hearing on the environmental assessment.

Conclusion

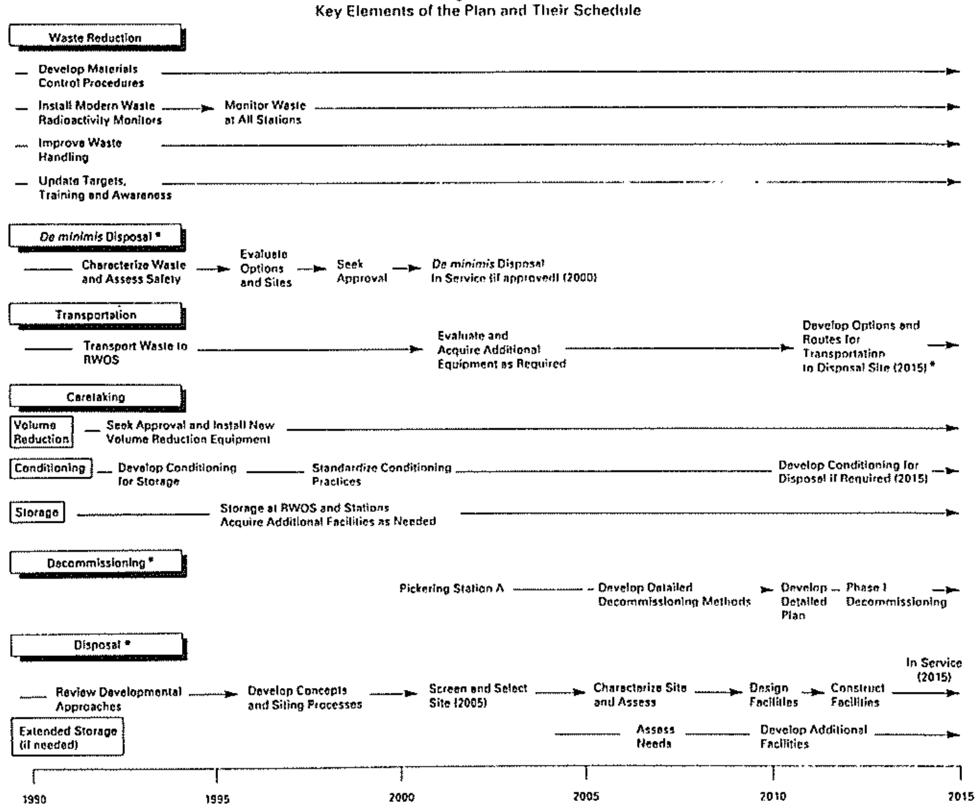
Ontario Hydro is committed to responsible and comprehensive management of all nuclear materials, including low and intermediate level waste from its operations. A Plan has been developed to accomplish this. Many decisions have still to be made and Ontario Hydro will periodically review the Plan taking public feedback into account.

Acknowledgement

The author acknowledges the members of the low and intermediate level waste management team: Jon Gee, Alanna Quin, Jim Cairncross, Frank Bajurny, Mohan Rao, Gerry Dicke and Brian Dalziel.

Peter Stevens-Guille is Manager, Radioactive Materials Management at Ontario Hydro and a former president of the Canadian Nuclear Society. Copies of the Plan referenced in his article can be obtained by contacting him at 416-592-6024.

Figure 1
Key Elements of the Plan and Their Schedule



* Public input will be sought for these activities

Demand Management
The Ontario Hydro Approach

by Ric Fluke

Ed Note: *Following is Ric Fluke's account of a talk by Marion Fraser of Ontario Hydro to the CNS Toronto branch.*

Ontario Hydro's 25-year strategic plan was updated in January 1992; plans to build up to ten new nuclear units have been deferred, and the Demand Management programme has become the top priority for the utility. Conservation is the main thrust of the programme, since "a kW saved is like a kW generated", but without burning fuel and without the environmental effects. To be sure, Ontario Hydro expects to spend about $6 billion to reduce demand by 5200 MW by the year 2000. Financial incentives will help consumers use less electricity by becoming more energy efficient. But the cost of these incentives are charged to the user through increased rates.

This was the focus of the presentation on "The Case for Demand Management", by Marion Fraser, manager of Energy Management Relations at Ontario Hydro, to the Toronto branch of the CNS in October.

Demand side initiatives for customers are not new. Oil companies have offered free "tune-ups", gas utilities have given assistance to purchase high efficiency furnaces, and telephone companies offer discounts for off-peak long distance calling. Many North American electric utilities now have some form of demand management programme, including Ontario Hydro. All of these programmes are intended to reduce demand in some way. The concept is simple: the company pays its customers to buy less of its product!

The concept is simple: the company pays its customers to buy less of its product.

Ms. Fraser cited a number of examples in Ontario Hydro's programme. A heating and cooling system is being installed at Brock University at a cost of $2.7 million, and is expected to save the university $250,000 annually. Cineplex Theatres have saved money after renovations in which energy efficient lighting was installed. Ms. Fraser noted that Ontario Hydro and its customers are not the only beneficiaries of the programme. There are spin-off benefits for companies like General Electric Canada Inc. and their employees who manufacture energy efficient lighting in Oakville, Ontario.

Part of Ontario Hydro's effort is in removing the barriers and myths about energy efficiency. For example, when calculating the cost of lighting a building, only the hardware and labour are often considered; in fact, 88% of the cost of lighting is electricity! Home builders do not incorporate energy efficient products because it raises the price, even though the buyer would recover those costs. This is why financial incentives and education are a major component of Ontario Hydro's plan.

Should we all run out and buy new energy efficient windows, refrigerators, lighting, furnaces, heat pumps and microwaves? No. As Ms. Fraser pointed out, it simply would not be cost effective for the customer. However, if you need a new refrigerator or if you are adding a new addition to your home, then you would benefit by purchasing energy efficient products. Although the up-front cost is high, financial incentives make it more affordable, and the products will pay for themselves through reduced monthly billing.

Eventually, there arises the question of who pays for these incentives. Ms. Fraser openly pointed out that demand management programmes increase rates. That is why there has been a new emphasis in the selling of demand management. The programme is now referred to as "Energy Management", with a customer focus. Ms. Fraser explained that demand management benefits the utility whereas energy management benefits the customer. For the utility, new generation is not needed, and hence there is less financial risk. For the customer, the total monthly bill is reduced even though the ¢/kW-h goes up. Customers can also receive financial assistance to become more energy efficient, as a further benefit. The strategy includes three-way partnerships with Ontario Hydro, the companies that manufacture energy efficient products, and customers that buy the products which use electricity. In fact, as Ms. Fraser explained, people don't want electricity. They want the services and products that use electricity – cold beer, hot showers, bright lights and toast.

Most engineers are sceptics, and this proved to be no exception after Ms. Fraser presented the case for demand management. In fact there was no conservation of energy during the lively debate. Many raised concern that people who do not participate in energy saving programmes are subsidising those people who benefit from the incentives provided by Ontario Hydro. One participant felt this would lead to economic distortions, citing as an example the chaos created by Market Value Assessment Programmes. Some felt this to be yet another example of government imposed taxation to coerce people into using less electricity. Those customers that do not become more efficient will not only use more electricity, but will pay more for it.

Ms. Fraser explained that, due to legislation affecting rates, demand management is not on "a level playing field" with capital projects for new supply. New supply is financed through borrowing; users are not charged until the new plant goes into service. But demand management is immediately charged to users. To be consistent, Ms. Fraser proposed that the cost of demand management be deferred until the current surplus supply is used up. (Note that the Ontario Energy Board, in reviewing Ontario Hydro's application for a rate increase, criticised the demand management programme, even though much of the 7.9% increase is due to the "rate shock" of the accumulated interest charges which financed Darlington before it came on line. Also of note, the New Brunswick Electric Power Commission, under attack for its 4% rate increase, announced that it would only implement those demand management programmes that do not increase rates.)

The debate was lively and provocative, and whether the audience agreed with the policies of demand management as presented by Ms. Fraser, there is no doubt that she was given full attention and appreciation by all who attended.

Nuclear Safety in Eastern Europe

In June 1992 the Canadian government announced a $30 million fund to assist the countries of the former USSR to upgrade the safety and reliability of their nuclear power plants. Of that amount $12 million has been approved-in-principle for programs to be administered by AECL CANDU. The Canadian program will concentrate on three areas: nuclear safety, regulatory systems and utility operation. AECL's partners are the Atomic Energy Control Board and Ontario Hydro.

AECL CANDU proposes to establish a Canada-Russia Nuclear Safety and Engineering Centre, with two offices in Russia, in Moscow and in Sosnovji Bor (near St. Petersburg).

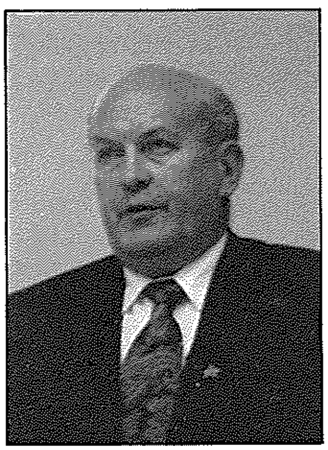
The AECB has had discussions with nuclear regulatory people in Lithuania, Russia and Ukraine. AECB officials report that the situation in those countries differs markedly, e.g., Lithuania has only 7 people assigned to nuclear regulation and is trying to establish a nuclear regulatory system while Russia has an existing regulatory organization with a staff of about 2,000. Also the AECB has been assisting the re-organized Romanian regulatory organization since last spring when members of that agency came to Ottawa for training.

On November 24, Dan Meneley, of AECL CANDU, spoke to the Toronto branch of the CNS on this subject, under the title of "Improving RBMK Safety". Highlights are printed below.

Improving RBMK Safety

by Dan Meneley

***Ed. Note:** The following is taken from Dr. Meneley's notes for a talk to the CNS Toronto Branch, 24 November 1992.*



Dan Meneley

Status of VVER and RBMK Reactors

According to the established regulatory rules in Western countries most, if not all, of these reactors would now be in violation of operating license conditions. They would be required to undergo substantial upgrading of safety characteristics (hardware, procedures, training, QA, etc.). Some of the plants require immediate repair.

Nevertheless, drastic steps such as shutdown are now generally recognized as impossible due to the economic and personal hardship which would be involved. National authorities in these countries also recognize the situation and will not consider this action; it is they, after all, who are responsible for the safety of their citizens. With or without the help of Western countries, the nuclear safety situation will improve slowly.

There *are* some real safety concerns. The common weakness of all these plants is that they do not have complete, fully-capable containment buildings surrounding the primary cooling systems. There are varying levels of confinement, or Accident Localization, systems which have the same role as our containment structures; these systems are much more complete and effective in newer versions of these plants.

We must remind ourselves that the inclusion of a containment structure on Western plants was by no means automatic; according to a paper written by George Laurence, containment was recommended in the US in about 1955, based on the *a priori* assumption that sudden and massive releases of fission products from a reactor core might occur for unspecified reasons.

A fact apparently recognized was that, if and when such an accident did occur (as at Chernobyl-4), the energy release could seriously challenge the integrity of the strongest containment structures such as we know them today. This fact puts a premium on limiting the reactor core's energy release – and hence the early insistence on strong negative power coefficients in US plant designs (especially those with pressure vessels).

Canadian design philosophy was probabilistic from the beginning – two independent, redundant and testable shutdown systems accomplish the same goal following an accident, so as to prevent serious overpower transients.

A different approach was taken in the Soviet Union – a high integrity containment structure was not required. In the normal approach to design for defence in depth, *this* design choice should have mandated more conservative safety systems; it did not. Shutdown systems were slow and weak, in spite of the design having a large positive cooling void coefficient. Operating practices were lax in the extreme. Regulations were quite lax in the early days; all controls have become more rigid in recent years.

A second major difference between Eastern and Western designers is the Eastern tendency to rely much more on operating staff actions and the Western tendency to rely more heavily on automatic systems. This is almost certainly a direct result of the differences in electronics technology or, to be more precise, its lack of availability for application in civilian facilities in the former Soviet Union (FSU). The FSU had a weak safety regulatory structure – as they were not subject to the "regulatory extremism" which has been evident on occasion in the West.

General economic conditions

Many industrial facilities have stopped operating in this area.
Food is in short supply.
Replacement parts are hard to get and are of low quality.
Salaries are low and sometimes not paid.

Plant conditions – recent changes

In spite of difficulties, the plants are generally running well. Several upgrades have been or will be installed.

Motivations

Why should we be worried about these reactors? Surely this is a question with which the eastern countries themselves must deal.

The new factor which has emerged since the TMI-2 accident in 1979 and the Chernobyl-4 disaster in 1986 is a recognition that the reputation of our nuclear industry is an international one; all of us are judged by the performance of the weakest member of the nuclear club. Individuals, professional organizations, and governments appear unanimous on this point.

The concerned attitude of many people seems to be formed largely through self-interest, driven by public acceptance concerns in the various Western countries.

The Question of Financing

The clearest indicator of Western attitude is the almost exclusive use of loans rather than grants to finance the safety improvement efforts of East European and FSU countries.

The EC goes as far as to prohibit use of their funds to support any contractor who is not based in an EC country.

The Canadian Program

Romania

There are many parts to the nuclear power question in Eastern Europe and the former Soviet Union. AECL is involved to some extent in Romania, Russia, Lithuania, and Ukraine; our strongest commitment is to the CANDU project in Romania, consisting of 5x600 MWe units under construction.

Canadian and Italian companies, under AECL's project management, are deeply involved with completion of the first CANDU 6 unit at the Cernavoda site; the remaining units will be completed as and when the Romanian government decides to proceed. This project was initiated when Romania was still a communist state. Many difficulties were encountered under the old regime in control of project activities, quality of workmanship, project schedule, and so on. These problems are being corrected under a Canada-Romania agreement involving the present democratic government.

Since the reorganization of this project it has been examined by the IAEA and other organizations; assurance has been received that Cernavoda Unit 1 now is being constructed completely up to Western standards. Extensive training of Romanian operating staff is underway; nonetheless, AECL will operate this unit for 18 months following startup in order to be sure that Romanian crews reach full capability before turnover.

Soviet Union

The countries of the former Soviet Union were essentially closed until 1989-1990. Since then, Canadian operators and designers have participated in OSART (operational safety and review team) and ASSET (assessment of safety significant events team) missions with the International Atomic Energy Agency (IAEA) and various inspections with the WANO (World Association of Nuclear Operators) organization. AECL has had low level technical contacts with the Russian program for many years, especially since the Chernobyl accident in 1986. Since 1990 the scope of this contact has increased steadily.

In early 1991, AECL initiated contact with the Kurchatov Institute in Moscow, with the general purpose of developing business relationship in the area and a long-term objective of promoting the introduction of the CANDU system into Russia and other FSU countries. Several agreements already have been reached involving various commercial possibilities.

AECL decided to concentrate our safety assistance activities on the upgrading of the Russian-designed RBMK reactors, since several countries already had started work on the VVER (PWR) units in FSU and Eastern Europe. Also, the RBMK and CANDU reactors are similar to the extent that they use multiple channels rather than a single, large pressure vessel. In addition both reactors employ on-line fuelling, computer control, and are susceptible to Xenon-initiated power instability.

As expected, there are different political influences in this international operation. Germany is working hard to convince the G24 group that all RBMK's should be shut down now; they use the World Bank loan promises as a lever. This approach does not find favour in Russia or, in fact, among most Western countries. Canada's position is that the economic need for electricity must be heavily considered in any shutdown decision; in any case, there is no practical means of forcing Russia to comply. Recent information reinforces the opinion that these plants are not so unsafe as to require early shutdown.

The Canadian safety assistance program in Russia consists of the Nuclear Safety Initiative (AECL, Ontario Hydro, AECB) plus participation in the Western Consortium. These activities will continue for 3 years, separate and independent from commercial ventures being undertaken by AECL.

Western Consortium

First steps

When the glasnost policy was introduced to the Soviet Union, many private firms and government agencies from Western countries started to form working contacts with various states and agencies. These relationships became very complicated, confusing, and sometimes duplicative; there was an obvious need for coordination among them.

In October 1991 the Russian design organization RDIPE (research and development institute for power engineering) sought the assistance of Western technical experts from government organizations already active in Russia. The reason for this request was that Russian organizations were being swamped by conflicting requests for bilateral cooperation from different directions.

Six government-owned nuclear agencies, from Britain, France, Italy, Germany, Sweden, and Finland, were asked to join an International Project with the purpose of assisting RBMK plants in Russia, Lithuania, and Ukraine. The Western part of this consortium is headed by AEA Technologies from the United Kingdom.

During this same period, Ontario Hydro's New Business Ventures Division was establishing contact with the newly-independent Baltic states (Lithuania, Latvia, Estonia). Various other business contacts are in place with Canadian companies.

Canadian membership

Finnish (STUK) and Swedish (SKI) members of the Western Consortium have been funded for more than a year by their own governments. The four representatives of European Community countries have now received funding for a one-year project from the Brussels secretariat. AECL joined in January 1992, but has not yet received funding from the Canadian government.

AECL has so far carried the costs of participation in the Western Consortium, in the expectation that funds eventually will be released by the Government of Canada. Expenses for attendance at a few meetings have been supported by the Department of External Affairs. One task group leader and expert members of various other task groups have begun work.

Future activities

Privatisation is a strong theme all around the world; government agencies have neither the money to fund large-scale assistance nor the structure to permit the existence of free enterprise. At the same time they are unwilling to relinquish control.

Hopefully, the Western Consortium will continue as a major scientific and technical communication link between East and West; some pressure to adhere to bureaucratic instructions already is being felt. Logically, the IAEA is best placed to fill this role by right of its mandate as a UN agency. However, this is a UN agency acting under a Board of Governors and with a multinational management. They can coordinate study and assistance activities, but cannot effectively manage commercial projects.

The Canadian Spring Initiative

Origins

This initiative was undertaken by AECL in the early spring of 1992 in response to a request from Canadian government officials to identify worthwhile activities which could be undertaken by Canada on behalf of Russia. Proposals were submitted in April under the heading "The Canadian Spring Initiative." These proposals were accepted and the initiative was announced by Prime Minister Mulroney during his television press conference with President Yeltsin of the Russian Federation.

Consistent with the deliberate pace of government organizations, up until now Ottawa has not actually released the money necessary to establish the Canada-Russia Nuclear Safety and Engineering Centre. At the present time it is planned that the Centre will establish offices in Sosnovji Bor near St. Petersburg, and in Moscow. The role of this Centre is to work directly with the plant operating staffs of each of the RBMK plants in turn, with the objective of helping them to upgrade operations.

Status

At this time a pre-project proposal is being discussed. This three-month effort will be devoted solely to the definition of the next phase involving actual work in Russia.

Other Programs

Bilaterals

Industrial activities are increasing slowly but steadily in many areas, including nuclear plant support. Most of these deals have required loans from the European Bank for Reconstruction Development or the World Bank.

Bilateral assistance agreements have been made between various companies in the nuclear field, including AECL and Ontario Hydro. These agreements have been mostly aimed at provision of intellectual assistance, since very small amounts of money are involved. The US started very slowly, but recently has accelerated its programs through a combination of government and private initiatives.

International Atomic Energy Agency

The IAEA technical assistance programs have generally excluded Russia; this is at the choice of the Russian government. A number of OSART and ASSET missions are planned in the near future.

G-7 Countries

RBMK plants were not evaluated in the first round of Western assessment – all in FSU, further from Western Europe. The July 1992 meeting of the G-7 concluded that *all* RBMK plants should be shut down as soon as it becomes feasible. Implied is that equivalent plants in UK, Canada (with positive reactivity coefficients) and other countries also should be shut down .

Vienna Conferences

In April 1992, IAEA convened a Technical Committee Meeting on the Safety of RBMK reactors, in Vienna. At this meeting, the Russian design authorities presented several papers describing both those improvements already made to all operating RBMKs after the Chernobyl accident, and further improvements now in progress on the older plants. Evgeny Adamov drew a direct connection between these plants (as upgraded) and similar plants in the West which have been licensed under older regulations and which are still operating.

A second conference on RBMK safety modifications was recently held in Vienna. It was apparent at this conference that only technical staff previously familiar with channel reactors had a reasonable understanding of RBMK. A further conference was held in Vienna at the end of November 1992.

Chicago Workshop

The American Nuclear Society sponsored a 1½ day workshop in Chicago following its November conference. Many senior representatives from Eastern countries took part along with representatives of most Western countries.

The proceedings of this workshop are not yet published. The most important (and nearly unanimous) conclusion of the meeting was: now that we understand the technical aspects of VVER and RBMK reactors better, and now that we understand the expertise and operating skills of the nuclear communities in these countries more completely, we recommend that all parties cease calls for early shutdown of these power plants, and that we spend our energies on improving the safety of all these plants.

Conference Reports

The Third International Conference on CANDU Fuel

by Paul Fehrenbach

The Third International Conference on CANDU Fuel was an unqualified success, with about 90 registrants representing Korea, Romania, Argentina, India, Japan, the United Kingdom, the United States, and of course, Canada. Sponsored by the Canadian Nuclear Society, the conference was held in Pembroke, Ontario, 4-8 October 1992. About one-third of the 50 technical presentations were authored or co-authored by members of the international CANDU fuel community.

The conference opened with a welcoming address by Dr. D.F. Torgerson, AECL Research Vice-President of Reactor Development. He noted that this was the third in a successful series of international conferences focused on CANDU fuel development and acknowledged the growing international participation. The increasing number of countries and organizations participating in development of CANDU fuel was an indication that CANDU is a mature and competitive power reactor concept with a growing acceptance worldwide, he observed. One of the unique advantages of CANDU is the relative simplicity of CANDU fuel design which makes it possible for countries who adopt CANDU to more readily develop a domestic fuel industry. The increasing international activity in CANDU fuel development makes the opportunity to meet with other technical experts en-

Several of the foreign delegates join with organizers at the 3rd International Conference on CANDU Fuel in Pembroke, October 1992 L. to R. Dr. Colin Allan, vice-president, AECL Research; Dr. Paul Fehrenbach, AECL Research, CRL; Dr. Ho Chun Suk, KAERI, Korea; Joseph Lau, Ontario Hydro; Dr. Constantin Georghiu, Institute of Nuclear Research, Romania; Dr. K. Balaramanoorthy, Nuclear Fuel Complex, India; Paul Boczar, AECL Research, CRL; Raul Olezza, CNEA, Argentina.

gaged in the design, analysis, testing, operation and handling of CANDU fuel increasingly important. He was therefore pleased, on behalf of AECL, to support CNS initiatives in organizing these International CANDU Fuel Conferences.

The guest speaker at the conference banquet was Dr. C.J. Allan, AECL Research Vice-President of Environmental Science and Waste Management, who spoke on "AECL's Concept for the Disposal of Nuclear Fuel Waste and the Importance of its Implementation." After describing the concept, he noted that AECL will soon be submitting an Environmental Impact Statement (EIS) on the Concept to a federal environmental assessment review panel. If the concept is accepted, he recommended that Canada should continue its responsible approach and take the next steps towards constructing a disposal facility for Canada's used fuel wastes.

The ten technical sessions of the conference focused on the following topics: International Experience and Programs; Fuel Behaviour and Operating Experience, with individual sessions on Normal Operating Conditions, Darlington Fuel Examinations, and Accident Conditions; Fuel Modelling, with individual sessions on Thermal, Mechanical and Irradiation Behaviour, and on Fission Gas Behaviour; Fuel Design, Testing, Manufacturing and Handling, with individual sessions on Fuel Design and Testing, Fuel Manufacturing, and Handling at Stations and Spent Fuel Management; and Advanced Fuel and Fuel Cycle Technology. Summaries of individual sessions, provided by the Session Chairmen, are given below.

The conference ran extremely smoothly due to the timekeeping efforts of the Program Chairman, Peter Boczar, and the cooperation of all of the speakers. The efforts of the Organizing Committee were also evident in the smooth operation of all other aspects of the Conference. The social events organized by the Chalk River Branch of the CNS, especially the Monday night barbecue, were enjoyed by all.

Peter Boczar indicates that the full proceedings of the conference are set for printing and are expected to be issued to each participant before Christmas.

Based on the response of participants to a post-conference survey, and the fact that the pace of CANDU fuel development is increasing, it is proposed that the Fourth International Conference on CANDU Fuel be held in about two years, again in the Chalk River area.

Session 1: CANDU Fuel – International Experience and Programs

Five papers were presented at this session. The papers covered the highlights of the national programs of Romania, Korea, India, Argentina, and Canada. Although the papers were of a general (overview) nature they all reflected a buoyant fuel development atmosphere in their respective countries.

Over the past 20 years the Romanian fuel industry had reached a high level of development, culminated by the production of 33,000 CANDU-6 bundles. The fuel fabrication facility at Pitesti is now embarking on a new revitalization phase which is expected to culminate in the qualification and certification by AECL of the facility to produce CANDU-6 fuel.

The CANDU program in Korea has just received a major boost following the commitment by KEPCO to build Units 3 and 4 of the Wolsong station. KAERI is expecting to be transferring its highly successful fuel fabrication expertise to KNFC. This will allow KAERI to focus on R&D. Two exciting projects for which funding has been secured include development of CANFLEX (jointly with AECL) and feasibility study of DUPIC (jointly with AECL and US-DOE).

Self reliance in the entire nuclear program has been the driving principle in India for some time. This objective was achieved some time ago in the area of "nuclear fuel cycle." Due to the expanding nuclear program, accelerated effort is required on the fuel development and supply fronts in order to meet the expected demand.

Argentina has also been self-sufficient in the "nuclear fuel cycle" program for some time. Efforts are now being turned to improved economics and security of supply in some critical components of the cycle, e.g., uranium mining, purification and conversion to UO_2.

The Canadian fuel development program continues to be very active on two fronts, improvements of the natural uranium fuel cycle and development of strategic components of the advanced fuel cycle. Funding for these programs is provided by COG and AECL, respectively.

M. Gacesa
H.C. Suk

Session 2.1: Fuel Behaviour and Operating Experience – Normal Operating Conditions

Six papers were presented during this session on the first day of the conference. Experience on defect rates was presented in three of the papers. Statistics were projected for Pickering. Point Lepreau and the seven Indian PHWR's. The role of bundle design and manufacturing techniques on defect rates was also brought in. In particular the paper by Manabendra Das presented their evolution to graphite coating, chamfered elements, and, interestingly, to large grained fuel. The two papers presented by Mark Floyd illustrated the capability of hot cell examinations to explain fuel performance. They also gave some interesting insight into the dependence of details of bundle manufacturing on fuel performance. In this session only the paper given by Al Manzer discussed the interpretation of GFP data, although radio-iodine concentration in Pickering was given by Mike O'Neil. The fourth subject area covered by the papers was the performance of high burnup fuel. Both the examination of the Bruce bundle and the thermal conductivity work by Petru Lucuta on SIMFUEL shed significant light on the behaviour of fuel in this regime.

Overall the papers gave an optimistic view of the industry's ability to control defects and to further improve fuel performance.

R. Gibb

Session 2.3: Fuel Behaviour and Operating Experience – Accident Conditions

The six papers in the session covered a wide range of topics, including mechanical fuel behaviour during accidents, reaction of Zircaloy and UO_2 at high temperatures, results from out-pile fission product release and in-reactor loss-of-coolant tests, and the safety analysis of in-reactor experiments.

In the paper by Mathew *et al.*, test results on the disassembly behaviour of irradiated CANDU bundles under impact were described. The results demonstrate that tests using irradiated bundles at 300°C and tests using unirradiated bundles at room temperature produce similar element cluster size. The finding allows the application of unirradiated bundle data to irradiated bundle situation.

In the paper by Das *et al.*, the mechanisms of PHWR clad strain during a postulated loss of coolant accident was discussed. Clad deformation leads to a reduction in flow sub-channel areas as well as potential clad failure. An ongoing program of ballooning and burst tests for PHWR Zircaloy cladding to develop failure criteria was described.

In their paper, Hayward and George reported the measured solubilities of UO_2 at 2000°C and 2200°C in oxygen-free Zircaloy and at 2200°C in oxygen-saturated Zircaloy. The solubility values and reaction paths during fuel dissolution and subsequent melt crystallization were discussed with reference to phase equilibria in the U-Zr-O system. The results are important for the prediction of fission product release from fuel due to the dissolution process following a severe fuel damage accident.

In the paper by Walsworth, a scope and methodology that may be used in the preparation of the safety and hazards analysis for nuclear fuel experiments was discussed. In an example, the scope of the safety analysis report for the BFT-104 severe fuel damage test was presented. The analyses are part of the process to ensure adequate protection of the operators, the experimenters, and the general public during the tests.

Cox *et al.*, reported the kinetics of fission-product release from high-burnup CANDU power-reactor fuel measured in hot-cell post-irradiation annealing experiments. Zircaloy-sheathed specimens were heated in inert conditions and then exposed to flowing steam at 1350°C or 1500°C. A specimen from a previously defected outer element was also tested for comparison to intact fuel. The results are important to the understanding and modelling of fission product releases during the high temperature accidents.

In their paper, DeVaal et al. presented the results of post-test thermalhydraulics and fuel behaviour simulations of the BTF-107 experiment. The thermalhydraulics simulations were performed with the CATHENA code, and the fuel behaviour simulations were performed using the ELOCA-Mks code. The results of these simulations illustrate the capabilities of the codes and indicate possible areas for future improvements.

J.H. Lau

Session 3.1: Fuel Modelling – Thermal, Mechanical and Irradiation Behaviour

Five papers were presented in the session, covering the following topics: analysis of fuel temperature (India), code validation (Canada) and defect evaluation (3 papers, Canada).

The Indian paper, presented on the author's behalf by M. Das, described an analysis of the fuel temperature history and microstructure of an irradiated PHWR fuel element, using a combination of computer simulation and post-irradiation examination. Metallography provided an estimate of the maximum fuel centre temperature, which confirmed the complete temperature history generated by detailed computer simulation using the codes TRIVENI and PROFESS.

The paper by Hallgrimson *et al.* (AECL-CANDU) dealt with recent validation of the fuel performance code ELESTRES, using a database containing 133 irradiation histories with bundle powers and burnups as high as 124 kW/m and 470 MWh/kgU, respectively. Overall, the ELESTRES code was shown to demonstrate good agreement with experimental data for all the fuel characteristics examined, thus confirming it as a reliable tool for predicting CANDU fuel behaviour under normal operating conditions.

Over the past decade, fuel fabrication process improvements have resulted in a significant increase in UO_2 density and uranium mass in the fuel bundles produced in Canada. In the meantime, the power ramp fuel defect correlations up to four years ago were still based on data from earlier fuel and in particular experimental irradiations in NRU. The defect excursion in Pickering (1988), where many fuel bundles underwent large power increases at relatively high burnups, has triggered renewed interest in updating the defect correlations and formed the basis for the following three Canadian papers.

Notley put into perspective the important role of pre-ramp fuel power history on defect probability. His semi-empirical model (PRAMP) is based on the existence of a constant critical stress (deduced from available data) at which the sheath would fail. Embodying many algorithms from ELESIM/ELESTRES, the PRAMP model has been "tuned" using power ramp data from NRU, Pickering, and Bruce and could be included in reactor fuel management codes to assess defect probability as a function of varying power history.

Da Silva presented an updated version of Ontario Hydro's CAFE correlation as a result of his study undertaken after the discovery that the previous correlation, derived from earlier CANDU fuel experience, could not explain the severity and number of observed fuel defects in the 1988 Pickering excursion. His statistical analysis of Pickering data has led to an improved algorithm for estimating the probability of SCC failure in terms of burnup, final power and ratio of final to initial power. The model yielded good estimates of Pickering defects, as well as the small number of Bruce-37 element fuel failures. Da Silva believes that these operational variables can be supplemented in future with more physically based variables (such as temperature, stress, strain) in order to evolve a mechanistic model for SCC failure.

Tayal *et al.* described a semi-mechanistic approach to calculating the probability of fuel defects, focused on SCC at the circumferential ridges, where both stress and corrodents concentrate. The fuel defect probability can be given by a CAFE type of empirical expression with mechanistic parameters obtained using the ELESTRES/SHEATH/FEAST suite of codes. Furthermore, as demonstrated by an example involving AECL-CANDU's defect study for the Italian CIRENE fuel, this semi-mechanistic model is believed to have the potential of being applicable to other fuel designs and operating conditions.

In his closing remarks, the Session Chairman noted the trend toward a mechanistic approach to estimate defect probability and invited the speakers to return to the next conference to report on their progress along this line. Also, although a fair amount of effort is being spent on defect studies in Canada, the overall fuel performance record of CANDU fuel is excellent. The participants were rightly reminded of this perspective by the Conference Chairman Paul Fehrenbach in his statement at the closing of the conference.

R. Hu

Session 4.1: Fuel Design and Testing

The five papers in this session were well received and sparked considerable interest. This was obvious by the many questions and lively discussion that ensued following the presentations. Several times the question period had to be halted because of the "Red Light" and time limitations.

M. Das opened the Session with "Fuel Bundle Development and Type Testing in India." This generated interest since comparisons could be made with development of fuel in Canada. Dr. Georghiu talked about the "Irradiation Test Programme Aimed to Check Romanian Nuclear Fuel Behaviour," and summarized the wide range of fuel parameters investigated. Paul Chan, CRL, gave a very dynamic presentation on the "Role of Zr_XI_YC Compound in Minimizing SCC in Fuel Cladding." He explained why the graphite CANLUB layer chemically prevents SCC. Mark Floyd, OH, presented OH data that showed sheath strains have increased in the past few years due to increased UO_2 mass in the fuel bundles. Al Manzer, AECL, gave a paper "Heavy Fuel for CANDU-6; Design Considerations." The positive aspects of heavy bundles are increased burnup, lower UO_2 temperatures, lower stored energy, lower gas release. Negative aspects of high density fuel are the higher sheath strains. Discussions for and against high density and high volume fuel ensued.

D.E. Teed

Session 5: Advanced Fuel and Fuel Cycle Technology

The final session consisted of a look forward, with five presentations describing the status of programs on advanced fuel and fuel cycle technology for CANDU. The authors described several current programs to support introduction of alternate fuel cycles such as thoria (India) and slightly enriched uranium into CANDU, as well as the joint KAERI/US/AECL study to investigate the direct use of spent PWR fuel in CANDU (DUPIC). The session concluded with a paper by Boczar describing the development of a Low Void Reactivity Fuel Bundle for CANDU to meet international marketing requirements, and a vision of how the introduction of enriched fuel cycles could be managed.

I.J. Hastings

AECB consults female radiation workers

This fall the Atomic Energy Control Board held consultations with female radiation workers across Canada to discuss proposed new radiation dose limits.

In March 1991, the International Commission on Radiological Protection issued new recommendations that would lower dose limits for all radiation workers. These included a new limit for pregnant radiation workers on the principle that the foetus should be protected similar to a member of the general public. The present limit for pregnant workers is 10 millisieverts during the course of pregnancy. The proposed limit would lower this to a number comparable to the proposed new limit of one millisievert per year for the public.

There are about 9,000 medical radiation workers in Canada, of which two thirds are women. Dose records indicate that some women in this group would exceed the proposed new limits. This implies that some pregnant radiation workers would have to be transferred to non-radiation work during the period of their pregnancy. Some organizations are large enough to do this without difficulty but many smaller hospitals and clinics would have difficulties. That might mean such women would have to be laid off and that this could lead to discrimination against employing women in nuclear medicine.

The cross-Canada meetings, which ran from October 7 to November 12, were held in the anticipation that discussions of the problem would provide greater understanding and lead to an acceptable solution.

The AECB is now developing new proposed regulations based on the consultations which will be published in the *Canada Gazette*.

REMINDER

Membership fees for 1993 are now due.

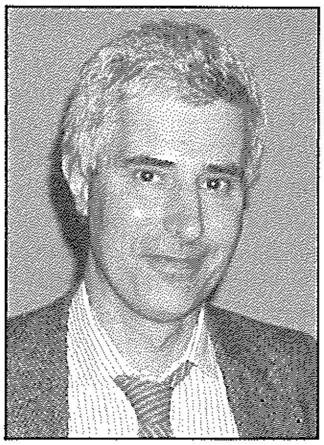
All members should have received a notice which should be returned as soon as possible to the CNS office with payment.

If you did not receive the notice (or have mislaid it) use the membership form enclosed in this issue.

You can also photocopy the form and give it to potential members.

CANDU Maintenance Conference

Reflecting the current emphasis in the nuclear industry, over 300 delegates convened in Toronto over the period 22-24 November 1992 for the Second International Conference on CANDU Maintenance. Delegates were treated to several incisive overview presentations and 57 technical papers on all aspects of maintenance related to CANDU nuclear power plants. To augment the flow of words 14 organizations displayed their equipment or services in a modest but informative exhibition which was also the venue for receptions, on the Sunday evening prior to the opening and at the end of the Monday sessions.



Tim Andreef

The conference was organized by the Canadian Nuclear Society with co-sponsorship of the Canadian Nuclear Asso ciation. Tim Andreef, of Ontario Hydro, was the general chairman, with Doug Benton, AECL CANDU, and Dan Meraw, Ontario Hydro, serving as co-chairmen of the technical program. George Fanjoy, formerly Ontario Hydro, provided advice from the first conference in 1987 and organized the plenary sessions.

The three papers of the opening plenary session provided the views of two station managers and a designer.

Henri Marois, of Gentilly 2, described the special problems of operating the only nuclear station in a large utility whose production is 96% hydraulic. The Gentilly 2 management has adopted a total quality approach with an objective of increasing availability and decreasing the length of planned outages, despite the ageing of the plant. The aim is to achieve a 90% availability (compared to the lifetime average of 79.3%) and to reduce planned outages to 21 days per year (from an average to date of 39 days).

(Marois's paper, in French, is included in this issue of the CNS *Bulletin*.)

Al Johnson, of the Point Lepreau G.S., offered a parallel paper, outlining how their continuous attention to detail has enabled his plant to achieve one of the world's highest lifetime capacity factors.

Presenting the designer's viewpoint, Ken Hodges, of AECL CANDU, referred to the new CANDU 3 design which has emphasized standardization and simplified design to meet maintenance requirements, improve accessibility, and ease replacement. He also spoke of the role of designers and research and development groups in maintaining the performance of ageing nuclear plants.

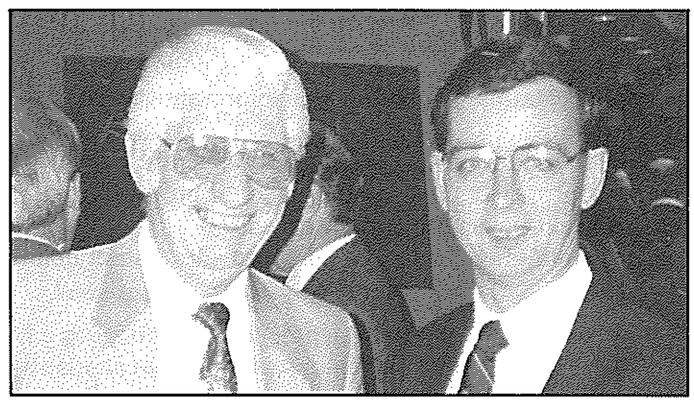
A closing plenary session featured Ken Talbot, manager of Bruce 'A' NGS, speaking on, "The Cost of Not Doing Maintenance – the Bruce 'A' Story." After several years of world record performance the maintenance budget for Bruce 'A' was cut by 20% in 1983 and continued over the following years. From a capacity factor of 91.4% for the four-unit station in 1984 operation deteriorated to 1990 when the capacity factor was only 45%. Not only were there more outages but their duration lengthened. A planned 90 day outage in 1989 stretched to 450 days.

Talbot outlined the remarkable turn-around in the past 1½ years and described the $3 billion retubing and rehabilitation program which is now being considered by the Ontario Hydro board. (The essence of Talbot's talk was in his paper in the summer 1992 issue of the CNS *Bulletin*, Vol. 13, No. 2.)

The 19 technical sessions dealt with topics such as: human performance; maintenance planning and resourcing; life cycle management; maintenance cost evaluation and control; innovative techniques; remote tooling; reactor maintenance; steam generator experience; instruments and control; and preventative maintenance. Full proceedings were available at the conference, making the discussion periods particularly lively. (The Proceedings can be purchased from the CNS office.)

An interesting and successful innovation was the inclusion in the program of three "open forum" sessions on the last afternoon. Delegates gathered in informal arrangements to share thoughts on steam generators, reactor maintenance and future trends.

Augmenting the technical presentations were three interesting talks at the two luncheons and the banquet.



Program organizers George Fanjoy and Dan Meraw take time out at the 2nd CANDU Maintenance Conference

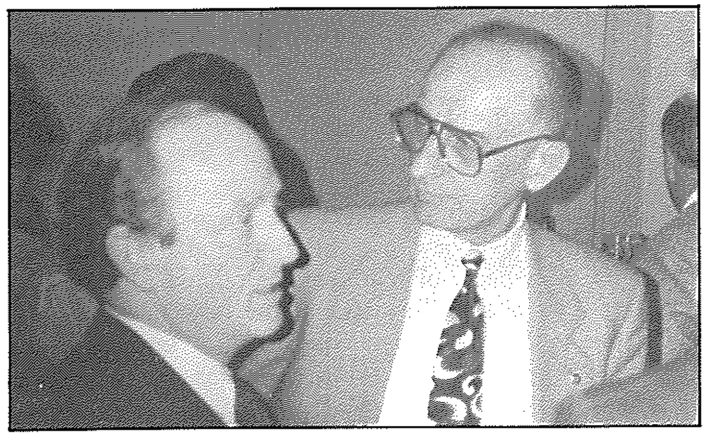
Roxanne Summers, the new CNS vice-president of communications, intrigued her audience with her comments on how people perceive and respond to risk, and stirred the mostly male group with her pointed comments on the absence of women in the industry. (Her remarks are reprinted in this issue of the CNS *Bulletin*.)

Chuck Baird, of NBEPC, emphasized the need to develop a sense of ownership among all those involved with a project. "Empower those doing the job to do what needs to be done", he urged. The new generation is much more prepared to work in teams than those nearing retirement, he asserted. Quoting Adm. Rickover (of US nuclear navy fame) he closed with the thought that responsibility can be shared or delegated but never avoided.

In a marked change from his usual acerbic style, Zyg Domaratzki, of the Atomic Energy Control Board, was remarkably complimentary in his after dinner talk. He noted that there had been many improvements in the operation of nuclear power plants in the five years since the first conference. Much of his talk focused on training on which he stated that, despite considerable progress, much still has to be done. For its part, the AECB is revising its operator examination system, with cooperation of the utilities. Some of the current written examinations will be replaced by tests on the station simulators.

Domaratzki supported the management improvements, especially those which involved more of the staff in identifying problems and planning the work. Maintaining the momentum will be difficult, he acknowledged, especially in the face of threatened budget cuts but is essential.

At the closing, program co-chair Dan Meraw commented, "It must have been an interesting conference, almost everyone stayed until the end." Many agreed with him and urged that organizers not let another five years go by before the next conference.



Ken Talbot, manager of Bruce "A" NGS, and Zyg Domaratski, director-general, reactors, AECB, both speakers at special sessions, confer during the 2nd CANDU Maintenance Conference in Toronto, November, 1992

La maintenance à Gentilly 2 à l'heure de la qualité totale

Michel H. Ross et Henri Marois

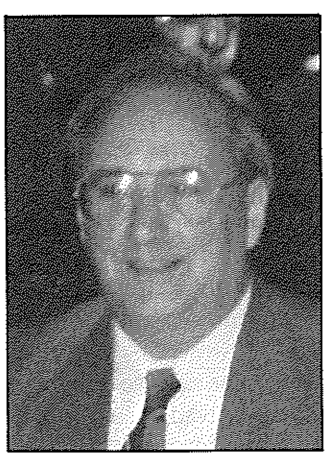
Summary

The station's maintenance policy aims at ensuring equipment availability through a management process seeking to balance resources and requirements. This policy has led to the implementation of comprehensive preventive maintenance programs.

Based on almost ten years of station operation, quality indicators provide a good measurement of how well customer needs and expectations are satisfied.

The commitment to total quality provides a strict management approach based on performance improvement and total customer satisfaction.

To improve overall performance to an annual availability factor of 90%, planned outages must be limited to 21 days a year and the preventive maintenance program must be upgraded. A quality improvement team is already involved in supporting this initiative. This team will seek to bring a new balance to the program and, eventually, optimize it using reliability-centered maintenance techniques.



Henri Marois

Introduction

En octobre 1983, Hydro-Québec a déclaré que Gentilly 2, centrale de la série CANDU-6, avait débuté son exploitation commerciale. Bien qu'elle soit une des principales compagnies d'électricité en Amérique du Nord, Hydro-Québec n'exploite qu'une seule centrale thermique classique et qu'une seule centrale nucléaire.

Dans l'ensemble, l'énergie qu'elle produit est à 96 % d'origine hydraulique. Il est à prévoir que l'entreprise continuera de faire porter ses efforts sur la valorisation de ses ressources hydrauliques par la mise en oeuvre de divers projets dans le Grand Nord québécois.

L'âge moyen des centrales nucléaires, dont Gentilly 2, augmente sensiblement, de pair avec les préoccupations engendrées par la maintenance. Au nombre de ces préoccupations figurent les coûts croissants de la maintenance proprement dite, de même que ceux de l'énergie de remplacement lors des indisponibilités de centrale. Plus important encore est l'incidence de la maintenance sur l'exploitation sûre et fiable de la centrale vieillissante. À long terme, la durée de vie de la centrale est, en bonne partie, fonction de la maintenance.

La politique de maintenance de l'enterprise a donné lieu à la mise en place de programmes élaborés de maintenance préventive. Après bientôt dix années d'exploitation, l'heure est maintenant et d'en évaluer les résultats. En s'engageant sur la voie de la qualité totale, l'entreprise s'est dotée d'un appareil de gestion qui lui permet d'augmenter sa performance globale et d'apporter les correctifs qui s'imposent.

La politique de maintenance

La politique de maintenance des installations de production d'Hydro-Québec vise à assurer la disponibilité des installations par des actions de maintenance appliquées à leurs éléments et à leurs composants. Elle s'appuie sur cinq principes généraux indissociables :

- la satisfaction des besoins des clients;
- la santé et la sécurité du public et du personnel;
- le respect de la législation et des engagements, tels les ententes et les conventions collectives;
- la protection de l'environnement;
- la rentabilité optimale de l'entreprise, par la minimisation des coûts et la maximisation de la disponibilité des installations.

Cette politique s'articule autour de deux grands axes. Le premier a trait à la disponibilité des installations et le second à la gestion de la maintenance.

La *disponibilité des installations* est assurée en maintenant leurs éléments dans un état spécifié, lequel est établi d'après les critères de conception, les conditions d'utilisation et les pratiques de maintenance. Dans ce but, des programmes préventifs d'entretien, de modification, de réfection et de remplacement sont mis en oeuvre de façon à minimiser la fréquence de défaillance des éléments des installations. Aussi, on établit des pratiques de maintenance qui minimisent l'impact d'une interruption de fonctionnement ou d'une détérioration des éléments des installations, et on modifie les éléments des installations de façon à faciliter les actions de maintenance.

La *gestion de la maintenance* est réalisée de manière à optimiser l'adéquation entre les ressources qui y sont affectées et les exigences relatives au bon fonctionnement des installations. Le mode de maintenance préventif ou correctif approprié est déterminé pour chaque élément des installations. Cette gestion tient compte des facteurs suivants : la planification, l'organisation, la réalisation, le contrôle, la rétroaction, et la recherche appliquée.

Maintenance

La maintenance est un ensemble d'actions exécutées dans le but de maintenir une installation ou un élément d'une installation ou un élément d'une installation dans un état spécifié. Ces actions comprennent l'entretien, la réfection, la modification et le remplacement d'éléments ainsi que leur remise en service consécutive à ces actions. La maintenance peut être réalisée selon le mode correctif ou préventif.

Mode correctif

Les actions de maintenance réalisées en mode correctif visent à rétablir le fonctionnement d'un élément suite à sa défaillance.

Mode préventif

Les actions de maintenance réalisées en mode préventif visent à prévenir la défaillance ou la détérioration d'un élément. Elles peuvent être déclenchées de façon systématique ou de façon conditionnelle.

De *façon systématique*, l'action de maintenance est effectuée en fonction d'un calendrier établi selon le temps ou le nombre d'unités d'usage.

De *façon conditionnelle*, l'action de maintenance est subordonnée à type d'événement prédéterminé, révélateur de l'état d'un élément.

Le programme de maintenance

En accord avec la politique de maintenance des installations de production d'Hydro-Québec et en accord avec le programme d'assurance de la qualité d'exploitation de la centrale, le programme de maintenance de Gentilly 2 a été mis en place.

Ce programme de maintenance s'étend notamment à l'ensemble des éléments suivants : organisation de la maintenance et de l'entretien, qualification du personnel, fonction de vérification, étalonnage, planification, dossiers d'entretien, procédures d'entretien, essais et mise en service, préparation et implantation des modifications, contrôle de la documentation, gestion des approvisionnements et des stocks, et contrôle radiologique.

Plus spécifiquement, la maintenance préventive englobe les six programmes suivants.

Entretien préventif

Le programme d'entretien préventif des équipements de la centrale regroupe l'ensemble des activités d'entretien visant à garder les équipements en état de remplir leurs fonctions avec un maximum de fiabilité.

Inspection périodique

Le programme d'inspection périodique regroupe l'ensemble des activités d'inspection visant à garantir le bon fonctionnement et l'intégrité des systèmes et éléments essentiels à l'arrêt du réacteur et au refroidissement du combustible durant toute la vie de la centrale.

Appareils sous pression

Le programme de contrôle de la qualité des appareils sous pression regroupe l'ensemble des activités d'inspection, de réparation et de modifications touchant les appareils sous pression.

Soupapes de sûreté

Le programme de maintien de la certification des soupapes de sûreté regroupe l'ensemble des activités de prevention, de détection et de correction des non-conformités des soupapes de sûreté.

Vibrations

Le programme de contrôle des vibrations regroupe l'ensemble des activités de mesure et d'analyse des vibrations des équipements et machines tournantes visant à prévenir l'occurrence de bris catastrophiques, à réduire les arrêts imprévus et à assurer une utilisation optimale des équipements tout en permettant une réduction des coûts.

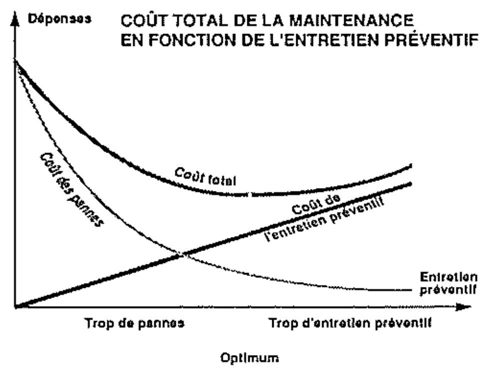
Essais prescrits

Le programme des essais prescrits regroupe l'ensemble des activités d'entretien préventif et des essais dont il est tenu compte dans les études de fiabilité pour garantir la sûreté de la centrale.

Le programme initial d'entretien préventif a été défini par les ingénieurs de mise en service d'après la réglementation et les spécifications techniques en vigueur, les recommandations du concepteur et du fournisseur, les résultats d'études particulières et l'expérience acquise par les exploitants d'équipement semblable. Ce programme, qui a été relativement peu modifié au cours des années, se révèle aujourd'hui de qualité inégale et laisse amplement place à l'amélioration.

La figure 1 présente la relation classique entre le coût total de la maintenance et le volume d'entretien préventif. La courbe de coût présente un optimum que tous recherchent. La revue en profondeur du programme d'entretien préventif par une équipe d'amélioration de la qualité est une démarche en ce sens.

Figure 1



Les indicateurs de maintenance

Les indicateurs de qualité sont des mesures du degré de réussite atteinte en matière de satisfaction des besoins du client et de ses attentes. Il s'agit, en d'autres termes, de la mesure du degré de conformité, de façon qualitative aussi bien que quantitative, à une exigence valable. En se fondant sur une valeur donnée de non-conformité, il y a lieu de s'attarder sur l'écart entre ce qui est et ce qui devrait être, entre la performance actuelle et les exigences du client. Les indicateurs donnent une mesure de la situation actuelle, de son évolution et des efforts à consentir en vue de son amélioration.

Indicateurs quantitatifs

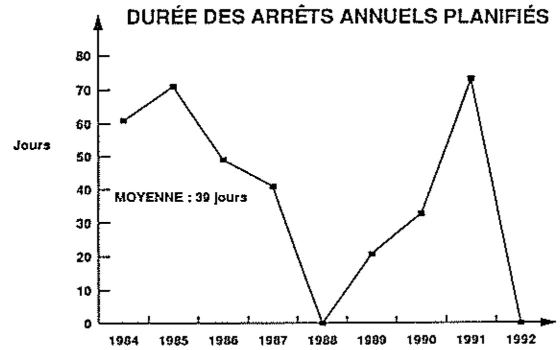
Le principal indicateur quantitatif est le coefficient de disponibilité équivalente. Celui-ci permet de mesurer selon quelle probabilité la centrale est apte à accomplir sa mission, soit produire de l'électricité pour son client qui est le réseau, en tout temps et selon les spécifications, y compris celles touchant la sûreté nucléaire.

À la fin octobre 1992, la valeur moyenne à vie de la disponibilité équivalente de la centrale était de 79,3 %. Cette valeur, quoique satisfaisante, doit être améliorée. Ainsi l'objectif pour 1995 est d'augmenter graduellement la disponibilité équivalente annuelle à 90,0 %. Il s'agit là de la principale cible d'amélioration de la centrale.

Indicateurs qualitatifs

Les indicateurs de disponibilité ne permettent pas de qualifier la satisfaction des besoins du client. Par exemple, le fait d'avoir une très bonne disponibilité en période de pointe

Figure 2



annuelle du réseau est un élément de satisfaction alors qu'un nombre relativement élevé d'arrêts imprévus devient une non-conformité par rapport aux attentes du client. En effet, le réseau doit maintenir une réserve de production adéquate pour faire face à ces arrêts. Le maintien de cette réserve est coûteux. De plus, chaque arrêt, planifié ou imprévu, impose des constraintes aux équipements. Ces transitoires s'additionnent avec le temps et deviennent éventuellement un facteur limitatif de la vie utile des équipements et systèmes. Enfin, chaque arrêt augmente les possibilités d'erreurs humaines et de défaillances additionnelles des équipements au cours de l'arrêt et du démarrage subséquent de la centrale.

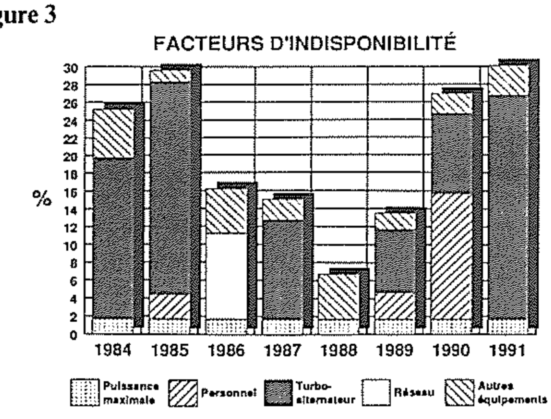
Le défi performance

En 1990, l'entreprise s'est engagée sur la voie de la qualité totale au moyen de son projet défi Performance. L'implantation du défi Performance s'échelonnera sur une période de cinq ans.

L'approche de gestion de la qualité retenue vise à satisfaire totalement et au moindre coût les besoins des clients par une plus grande mobilisation des ressources humaines et par la matrise des processus de travail. Il s'agit non seulement d'une philosophie qui permet l'implantation de valeurs fondamentales, mais aussi d'une technique en ce qu'elle formalise, par des méthodes scientifiques, un style de gestion rigoureux.

Pour soutenir la gestion de la qualité, l'entreprise s'est donné un nouveau modèle de gestion qui met en jeu quatre principes et trois axes de gestion, de même que des équipes de travail vouées à amélioration de la performance.

Figure 3



Ce modèle de gestion, qui allie des outils rigoureux d'amélioration de la performance et de satisfaction totale des clients, s'appuie sur des principes fondamentaux :

- L'*orientation client.*
- Le *respect des personnes.*
- La *gestion en fonction des faits.*
- L'*amélioration continue.*

Ces principes de la qualité débouchent sur des interventions concrètes dans les axes de gestion suivants :

- Les *cibles d'amélioration.*
- Les *processus de travail.*
- L'*assurance de la qualité.*
- Les *équipes d'amélioration.*

Le défi Performance est implanté progressivement à Gentilly 2 au même rythme que dans l'ensemble de l'entreprise.

Les équipes d'amélioration de la qualité adoptent une démarche qui réfère spécifiquement au processus de résolution de problèmes du défi Performance. Baptisée démarche Qualité, il s'agit d'une méthode systématique de recherche et de résolution de problèmes, fondée sur la cueillette et l'examen de données factuelles, qui comporte sept étapes :

- *Besoin d'amélioration.*
- *Objectif d'amélioration.*
- *Causes du problème.*
- *Mesures correctives.*
- *Résultats.*
- *Standardisation.*
- *Bilan et perspective.*

À chacune de ces étapes, l'équipe procède systématiquement à toute une série d'activités bien définies.

Les voies d'amélioration

La principale cible d'amélioration de la centrale sur quatre ans est une augmentation graduelle du facteur de disponibilité équivalente de 10 %, sans augmentation des coûts de maintenance.

Pour toucher la cible, deux autres conditions sont nécessaires : contenir le nombre et la durée des arrêts imprévus à leurs valeurs actuelles, alors que la centrale commence à vieillir, et réduire la durée moyenne des arrêts annuels planifiés de 39 à 21 jours. Ces deux conditions passent par une optimisation du programme d'entretien préventif.

Conditions facilitantes

Au cours des dix dernières années, beaucoup d'expérience pratique a été gagnée. La maintenance réactive des systèmes reliés à la manutention du combustible a cédé le pas depuis plus d'un an à un programme de maintenance préventive systématique et conditionnelle. Les indisponibilités de ces systèmes critiques pour le maintien du réacteur en marche ont été réduites de façon très substantielle.

L'important programme de maintenance conditionnelle des tubes de force du réacteur, bien qu'il puisse toujours être modifié, peut maintenant être considéré comme étant au point. Ce programme d'inspection, de surveillance et de remise en place des ressorts d'espacement permettra de matriser l'évolution de l'état de ces éléments essentiels et d'obtenir une durée de vie utile satisfaisante des canaux de combustible.

Le programme de maintenance préventive systématique, et de plus en plus conditionnelle, des générateurs de vapeur a déjà porté fruits. En effet, jusqu'à ce jour, aucun tube des générateurs de vapeur n'a dû être bouché pour cause de défaillance. Tout porte à croire que ces équipements critiques vont fonctionner de façon sûre, fiable et économique jusqu'à la fin de la vie utile de la centrale.

La durée des arrêts planifiés a presque toujours été dictée par les travaux relatifs au groupe turbo-alternateur. Ces arrêts ont été requis pour vérifier l'alignement, pour aligner les arbres ou pour réparer le groupe. Le désalignement continuel de la machine est causé par une réaction chimique dans le béton, qui fait gonfler le béton et qui engendre des déplacements inacceptables des composants de la machine. D'autre part, les fortes vibrations de l'alternateur sont dues à une trop grande flexibilité de la fondation le supportant. Après plus de quinze ans, il y a enfin une stabilisation relative des déplacements de la fondation. La maintenance préventive systématique est remplacée par de la maintenance préventive conditionnelle. Les inspections deviennent sectionnelles au lieu d'être totales. Dès l'année prochaine, l'arrêt annuel pourra être comprimé à 21 jours.

La gestion des arrêts planifiés est matrisée.

Le programme d'entretien préventif

Le programme d'entretien préventif doit être optimisé. Un nouvel équilibre est recherché. Une équipe d'amélioration mettant en pratique la démarche Qualité est déjà à pied d'oeuvre. Cette équipe est constituée de personnel venant de tous les groupes dont les activités sont liées à la maintenance : ingénieurs, opérateurs, contrematres, techniciens, gens de métier, planificateurs.

Un des problèmes cernés, soit le besoin d'amélioration, réside dans le fait que le programme d'entretien préventif actuel fait appel à de multiples interventions alors que la centrale est à l'arrêt. Jusqu'à ce jour, ceci n'a pas causé de difficultés importantes en raison de la durée moyenne relativement longue des arrêts annuels, mais des arrêts raccourcis à 21 jours font natre une nouvelle problématique.

Un autre besoin d'amélioration identifié par l'équipe est l'optimisation de l'entretien par la fiabilité.

Puisqu'il y a deux problèmes, l'équipe d'amélioration devra franchir chacune des différentes étapes de la démarche Qualité à deux reprises.

Conclusion

Les programmes de maintenance ont déjà donné de bons résultats. L'importance de la composante proactive, c.-à-d. la maintenance préventive conditionnelle, progresse continuellement au fur et à mesure que les programmes sont mis à jour. Par ailleurs, l'engagement de chacun à l'égard de la qualité totale permet d'augmenter notre performance globale. Le principal objectif visé pour 1995 est un facteur de disponibilité équivalente de 90 % annuellement.

L'approche de gestion axée sur la qualité totale vise à satisfaire totalement et au moindre coût les besoins des clients par une plus grande mobilisation des ressources humaines et par le matrise des processus de travail.

En particulier, le programme d'entretien préventif est scruté par une équipe d'amélioration de la qualité afin de lui redonner un nouvel équilibre et, éventuellement, de l'optimiser par la fiabilité. La marche continue vers l'excellence n'a pas de cesse.

Fifty Years Controlled Nuclear Chain Reaction: Past, Present, Future

ANS/ENS Conference

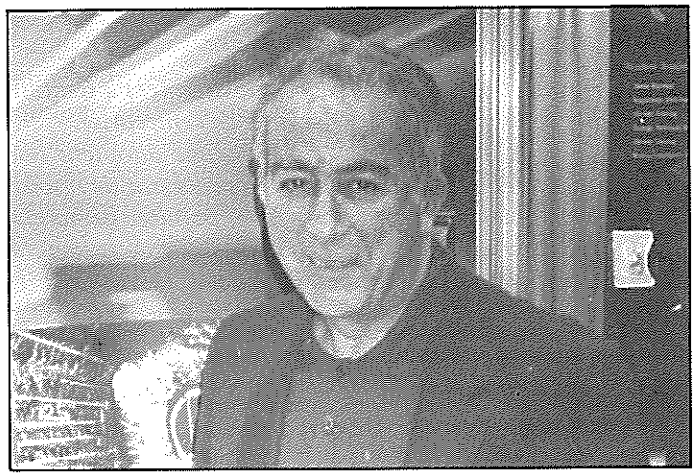
The 1992 joint meeting of the American Nuclear Society and the European Nuclear Society commemmorated the 50th anniversary of the first controlled nuclear chain reaction which took place December 2, 1942. On that day Enrico Fermi and his co-workers completed the construction of their graphite-uranium pile, designated CP-1 (for Chicago Pile No. 1) and took it to criticality. Although the event was just one step along in the whole enterprise of the Manhattan Project, it has come to mark the birth of the current nuclear era.

The theme of the conference was "Fifty Years Controlled Nuclear Chain Reaction: Past, Present, Future." Largely because of its historical emphasis the conference drew over 2,000 delegates from around the world to Chicago in mid-November, including many of the pioneers. Among those pioneers present were Bertrand Goldschmidt, who had been at Canada's Montreal Laboratory and later helped to create the French nuclear program; Alfred Nier, one of Fermi's team; and Glen Seaborg, who first separated plutonium and later became chairman of USAEC.

In his opening address Dr. Seaborg provided his large audience with a fascinating history lesson, with emphasis on his own particular interest, the trans-uranic isotopes. He referred to work of Hahn and Strassmann in 1938, demonstrating fission from the bombardment of uranium by neutrons, which was followed in 1940 by McMillan and Abelson's production of plutonium. Citing his own work, he noted the separation of ½ microgram of Pu 239 in early 1941 (from which its chemical and physical properties were determined) and shortly thereafter demonstrating the fissionability of Pu 239.

Dr. Glen Seaborg at the AECL exhibit

Later, at a press conference, Dr. Seaborg read from his diaries which he kept meticulously throughout his long career. (Subsequently, he sent the writer the pages covering his visit to the Montreal Laboratory in 1944.)



Ara Mooradian, formerly AECL V.P., gave a plenary paper on the Canadian program at the ANS/ENS Conference celebrating the 50th anniversary of the first nuclear reactor

Other plenary speakers, William Lee of Duke Power in the USA, John Collier, Chairman of Nuclear Electric PLC (UK), and Andre Giraud of France reviewed the programs in their countries and their views of the future.

The 16 honoured pioneers present held a special "reminiscing" session one evening which was well attended even as it stretched in length much longer than scheduled.

The actual technical conference included some 400 papers in as many as 15 parallel sessions, as is the usual ANS format. Scattered among these were several special sessions following the theme of the conference – past, present, future – but focusing on particular topics such as; materials management, criticality safety, public acceptance, reactor control.

An interesting and somewhat different session was on "The Atom and Human Values." In their opening remarks the panelists ranged from the problems in eastern Europe, to "sustainable" development and the contradicting demands for improved material living standards and protection of the environment. These triggered a lively discussion which had to be terminated in full flight when time ran out.

Accompanying the conference was a large exhibition. The most striking impression was that almost all of the exhibitors were offering services, many aimed at "ageing" facilities. There were few new reactor designs presented. Within the exhibition was a special historic display organized by the Argonne National Laboratory which included several displays from the Canadian program.

A statement issued by the 16 pioneers present and a short note on the first reactor are included in this issue.

Perspectives of Nuclear Pioneers

Ed. Note: *Sixteen nuclear pioneers were honoured at the ANS Conference on "Fifty Years of Controlled Nuclear Chain Reaction: Past, Present, and Future" held in Chicago 15-20 November 1992, in recognition of the first critical assembly of 2 December 1942.*

The sixteen were: Harold Agnew, Manson Benedict, Hans Bethe, Walker Cisler, Edward Creutz, Sigvard Eklund, John Foster, Andre Giraud, Bertrand Goldschmidt, John Hill, John Kuranz, Alfred Nier, Rudolph Peierls, Glen Seaborg, Chauncey Starr, Edward Teller, Alvin Weinberg, John Wheeler, Eugene Wigner, Rosalyn Yalow, Walter Zinn.

During the meeting the sixteen prepared and issued the following statement.

On this commemoration of the half-century anniversary of nuclear power development, a few of us who nurtured its early germination and flowering have gathered to look back and ahead to speculate on its role. While we are unlikely to be around a half-century from now to verify our speculations, many of you will be and presumably will make appropriate mid-course adjustments.

Prior to the nuclear age, the source of nearly all life-supporting energy was solar radiation. It has taken many millenia for mankind to learn to use the stored solar energy in coal, oil, gas, and biomass as a supplement to the direct warmth of sunlight. In this century we have found the photovoltaic cell to be a conversion device from sunlight to electricity. Biomass is potentially a source of transportation fuel. In the mythical temple of energy gods, the sun will reign supreme for a long time to come and deserves our continued worship.

However, the temple now makes space for a lesser god, nuclear power, brought forth from nature's secret archives by the nuclear pioneers that we represent here. It is the only addition to mankind's primary energy resources in recorded history, and we are confident that it will increasingly contribute to global energy supply. It appears on the global scene at a most timely period, when it has become apparent that fossil fuels, especially oil and gas, may be limited, and when the global environmental consequences of their use are being recognized. We have the rare lifetime satisfaction of having been principals in a most fundamental contribution to the future of mankind.

In the past 50 years much has been contributed to nuclear power development. The first half of this period provided exploratory demonstrations of several reactor concepts, and the second half gave the first commercialized versions of a few. As with all new technologies, it will take many cycles of improvements, new system concepts, and operational learning to reach its full potential. To many of us it is most satisfying to see nuclear electricity providing such a large fraction of the needs of industrial countries at such an early stage of its development.

A most significant contribution to human progress is the medical and research use of the radioisotopes made abundantly available as a by-product of these nuclear processes. It far exceeds the initial vision of the nuclear pioneers. Daily shipments of radioisotopes produced by nuclear reactors are utilized by thousands of hospitals and clinics globally in the broad span of medical specialities ranging from pediatrics to cardiovascular disease to dementia. The therapeutic use for targeting malignant disease is expanding greatly. The research applications in all the scientific fields have become part of the common tools of scientists everywhere.

And, as with all new technological developments, these experiences have disclosed problems whose resolution will contribute to the long-time growth of nuclear power.

Again, we should observe that the history of fossil fuel use is replete with difficulties that required centuries to overcome. Even today fossil fuels pose hazards that need societal management and accommodation. Concentrated energy forms will always have the inherent potential to be hazardous, and their acceptable use requires meticulous design, construction and operation. So we should not be surprised that nuclear power brings a new category of issues, arising from the possibility of accidents and consequent radioactivity exposures. Important for reactor safety is providing continued removal of the residual shutdown heat of the reactor, a special engineering objective. Another issue, which has concerned the public, is the radioactivity from spent fuel and the back end of the fuel cycle. Fortunately the science of containing radioactivity is well understood and we have no doubt that its engineering application will be successful.

Although the growth of the world nuclear industry is slowed at present by the state of the world economy and public opinion, nuclear power will come to be seen as a less polluting and more desirable choice than fossil fuels. We have great confidence in foreseeing a major global role for nuclear power in the future.

Deadline

The deadline for the next issue of the CNS *Bulletin*, Vol. 14, No. 1, Spring 1993, is 28 February 1993.

Chicago Pile No. 1

Ed. Note: *The following is drawn from a number of sources, in particular a book published by Argonne National Laboratory especially for the ANS/ENS 1992 conference, entitled "Controlled Nuclear Chain Reaction, The First 50 Years."*

On a Wednesday afternoon forty years ago a team of young scientists led by Enrico Fermi created the first sustained nuclear chain reaction. The historic event took place in a room under the Stagg Field Stadium at the University of Chicago, December 2, 1942.

In 1941, Fermi, a refugee from Italy, and Walter Zinn from Canada, had been working at Columbia University on possible designs for a uranium chain reactor. The study of graphite-uranium lattices was begun in July of that year. All of this had been triggered by the discovery of fission in 1938 and the flurry of research that followed.

After the creation of the Manhattan Project in early 1942 the researchers at Columbia and Princeton Universities were moved to the Metallurgical Laboratory established at Chicago. Work on graphite-uranium piles was continued.

By July 1942, there was sufficient information to consider the design of a test pile of critical size. Uranium oxide had to be used because metallic uranium of the required purity was not available. Several companies were working on this and by November several tons of the highly purified metal was delivered and used in the centre of the pile.

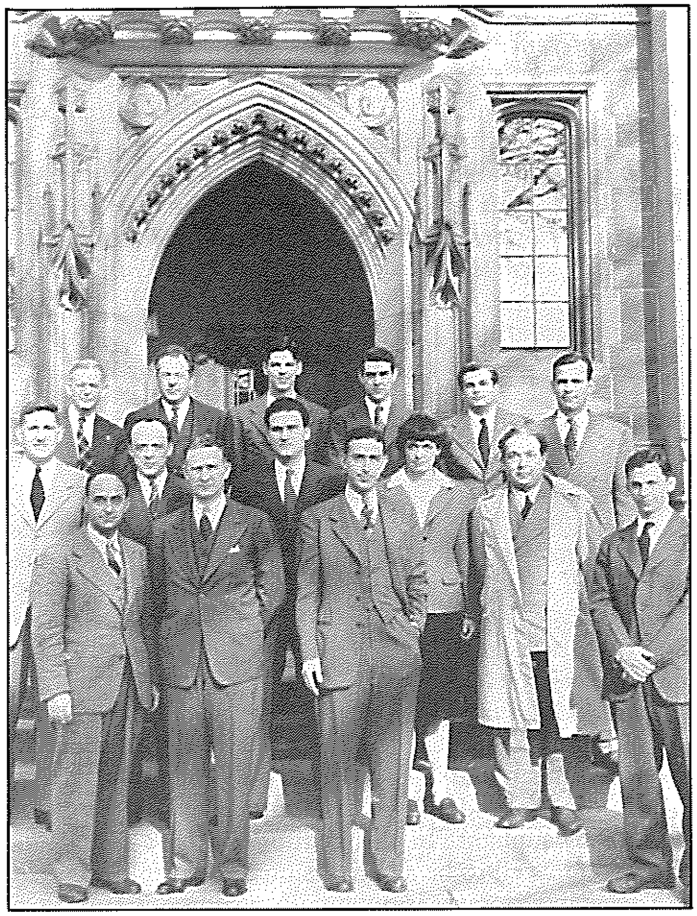
After having built 30 experimental piles construction of the main pile began on November 15 and named Chicago Pile No. 1 (CP-1). Fermi wanted to build the pile as close to spherical as possible to minimize the surface-to-volume ratio and therefore the leakage of neutrons.

Before the structure was half complete measurements indicated that the critical size would be somewhat less than anticipated. During the afternoon of December 1 tests showed that the critical size was being approached. At 4 p.m. when the last layer of graphite and uranium bricks was placed on the pile Zinn and an associate made several measurements and concluded that when the control rods were withdrawn the pile would become self-sustaining.

About 8:30 a.m. December 2 the group assembled in the squash court. At the north end there was a balcony where Fermi, Anderson and Compton were grouped around the instruments, with the remainder of the observers crowded behind.

The main control rod was a stick of wood wound with cadmium foil. There were two other sets of control rods. One was automatic and could be controlled from the balcony, the other was an emergency safety rod to which a rope was attached. This rod was withdrawn and tied by another rope to the balcony. Norman Hilberry was ready to cut this rope with an axe if the automatic safety rods failed. As a final safety measure "liquid-control squad" stood above the pile ready to pour cadmium-salt solution over it.

Following withdrawal of the automatic and emergency rods Fermi ordered the control rod to be withdrawn step by step. After each step Fermi would observe the galvanometer and make a calculation. Suddenly, after a step, the automatic safety rod dropped – the safety point had been set too low. Fermi called a halt and the team went to lunch.



Many of the CP-1 team stand in front of Eckhart Hall (the Metallurgical Laboratory building) at the University of Chicago on December 2, 1946, the four-year anniversary of the world's first self-sustaining, controlled nuclear chain reaction.

Front row, left to right: Enrico Fermi, Walter H. Zinn, Albert Wattenberg, and Herbert L. Anderson. Middle row: Harold Agnew, William Sturm, Harold Lichtenberger, Leona Woods Marshall, and Leo Szilard. Back row: Norman Hilberry, Samuel Allison, Thomas Brill, Robert G. Nobles, Warren Nyer, and Marvin Wilkening. (Photo courtesy of Argonne National Laboratory)

When they reassembled Fermi began the final stage, calculating the necessary withdrawal each time. Then the pen continued to rise. Fermi made several calculations with his slide rule and announced, "The reaction is self-sustaining; the curve is exponential." The group watched for about 28 minutes and then Fermi called to Zinn, "OK, zip in." The time was 3:53 p.m. and it was all over.

Right after Fermi ordered the reaction stopped Eugene Wigner presented him with a bottle of Chianti wine. Fermi uncorked it, served it in paper cups, and all drank a silent toast.

That afternoon, Arthur Compton, who was the director of the Chicago Metallurgical Project, telephoned to James Conant, the senior scientist of the Manhattan Project: "The Italian navigator has landed in the new world," said Compton.

"How were the natives?" asked Conant.

"Very friendly."

The Evolution of Canadian Research Reactors: 1942 to 1992

by R.F. Lidstone

Ed. Note: *The following article is extracted from a presentation Dr. Lidstone gave to the ANS Conference in Chicago, November 1992, which highlighted the 50th anniversary of the start-up of the first reactor in December 1952.*

The full paper, containing considerably more detail, is available from AECL Research as report AECL 10760.

Introduction

This paper reviews the evolution of Canadian research reactors during the first fifty years of fission reactors. The discussion is limited to the evolutionary mainstream including: early subcritical experiments, heavy-water-moderated reactors, light-water-moderated reactors, and current irradiation-research-facility studies.

Research reactors have played a central role in the Canadian nuclear program including the development of CANDU power reactors and the creation of a major radioisotope-production business. The design of Canadian research reactors has been based on developing and exploiting appropriate technology with each succeeding facility extrapolating from the existing technology base to meet the initial program objectives and to accommodate changing priorities.

Early Subcritical Experiments

As the scientist in charge of radium and X-ray research, nuclear pioneer George Laurence was aware of Canada's abundant uranium resources. Believing that isotope separation was beyond Canada's means, he began in March 1940 to experiment with subcritical lattices of natural uranium-oxide powder and the best available moderator, carbon in the form of calcined coke. He formed a primitive heterogeneous lattice with coffee bags of uranium surrounded uniformly by coke. Housing the core in a bin lined by paraffin, he used a radium-beryllium neutron source and built a set of Geiger counters to measure the flux distribution. Despite inconclusive results, the experience stimulated follow-up experiments in 1941-1942. A multiplication factor of about 0.90 was obtained with a larger ($8 m^3$) spherical core containing about 9 Mg of graphite and 0.9 Mg of uranium oxide in packages of 3 kg. It became clear that higher-density uranium and a more efficient moderator would be required to sustain a chain reaction.

Between 1943 and 1945, work at the Montreal Laboratory focused on heavy-water-moderated natural-uranium lattices. The subcritical facility comprised a cylindrical steel tank ($3.3 m^3$ in volume) filled with heavy water. Photoneutrons generated in beryllium by 2 MeV X-rays were directed upwards from a graphite block below the tank; cadmium sheets between the graphite and the heavy water avoided flux distortions due to reflected neutrons. The experimental program yielded buckling measurements of various lattices containing proposed uranium-metal fuel rods for the ZEEP critical facility and for NRX (*N*ational *R*eactor *X*-perimental), the first Canadian high-power reactor.

Heavy-Water-Moderated Reactors

One of the purposes of ZEEP was to perform measurements of lattice design, fuel-rod dimensions, and sheathing alternatives for NRX. Its main features were a large ($9 m^3$), graphite-reflected aluminum tank, into which heavy-water moderator could be pumped from a storage tank below. Experimental lattices were formed by hanging fuel assemblies from steel beams placed across the top of the tank. On September 5, 1945, ZEEP became the first reactor to operate outside the United States. It operated over the next twenty years to provide valuable information on the characteristics of heavy-water-moderated fuel lattices for the NRX and NRU research reactors, the NPD prototype nuclear-electric station, and early CANDU power reactors.

NRX is a heavy-water-moderated high-flux multi-purpose reactor with once-through light-water cooling. The large ($17 m^3$) reactor core provides 199 vertical sites for fuel assemblies, test loops, irradiation targets, and shut-off rods. When NRX first started up in July 1947, it was fueled with natural uranium-metal rods. The original maximum power of 20 MW was reached in January 1949 at which time the peak neutron flux was about 3×10^{17} $n \cdot m^{-2} \cdot s^{-1}$. Following the major accident in December 1952, the restoration program enabled uprating to 42 MW with a peak flux of 7×10^{17} $n \cdot m^{-2} \cdot s^{-1}$. By 1962, a peak flux of 1.2×10^{18} $n \cdot m^{-2} \cdot s^{-1}$. was reached via the conversion to HEU-Al-alloy fuel.

NRU (*N*ational *R*eactor *U*niversal), which started up in November 1957, is a large (23 m^3 volume) heavy-water-cooled and -moderated multipurpose reactor with 5 (initially 3) vertical loop positions, a thermal column, and a large array of neutron-beam holes. Originally designed for plate-type natural uranium-metal fuel, it generated a peak thermal neutron flux of 3×10^{18} $n \cdot m^{-2} \cdot s^{-1}$ at 200 MW. On-power refueling, later applied to CANDU reactors, permitted relatively long operating periods. Like NRX, NRU was converted to HEU-Al fuel rods to increase production of radioisotopes such as Co-60 and Mo-99. Although a flux increase to 2×10^{19} $n \cdot m^{-2} \cdot s^{-1}$ was feasible, the peak flux was limited to 4×10^{18} $n \cdot m^{-2} \cdot s^{-1}$ and the power was reduced to 115-135 MW.

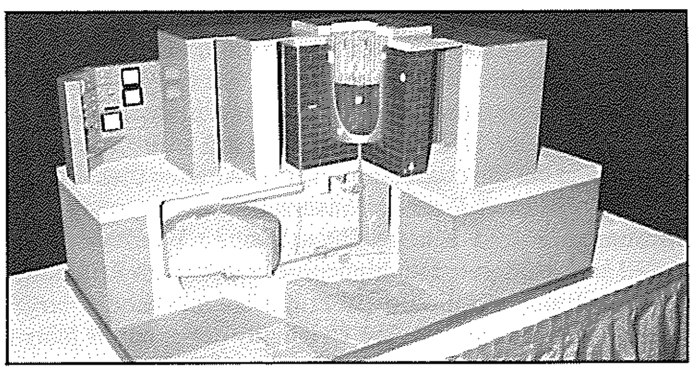
The use of natural-uranium fuel and heavy-water moderator for the NRX and NRU resulted in a relatively modest thermal neutron flux per unit power of 2×10^{16} $n \cdot m^{-2} \cdot s^{-1} \cdot (MW)^{-1}$. However, with the shift to HEU-Al fuel, a higher flux-to-power ratio of 3×10^{16} $n \cdot m^{-2} \cdot s^{-1} \cdot (MW)^{-1}$ was obtained. With fewer sites fueled, the in-core irradiation space also greatly increased. More recently, a low-enrichment (19.7%) version of the NRU fuel rod has been developed using U_2Si-Al to replace the U-Al fuel meat.

Light-Water-Moderated Reactors

The development of the SLOWPOKE reactor is significant for its neutronic efficiency and the inherent safety achieved in a low-power (20kW) low-flux (2×10^{16} $n \cdot m^{-2} \cdot s^{-1}$ thermal peak) research reactor. The flux-to-power ratio (5×10^{17} $n \cdot m^{-2} \cdot s^{-1} \cdot (MW)^{-1}$) is the highest practical level for U-235 fission. The limitation of excess reactivity to half of prompt critical avoids the need for engineered safety systems and full-time operator attendance.

The MAPLE reactor concept is intended to meet contemporary requirements for multipurpose research reactors. It combines the LEU fuel developed for NRU with Canadian heavy-water technology to provide an efficient neutron source (2×10^{17} $n \cdot m^{-2} \cdot s^{-1} \cdot (MW)^{-1}$ thermal flux per unit power in the reflector) in a 10-15-MW pool-type reactor facility. The MAPLE-X10 prototype employs a compact (63L) light-water-cooled and -moderated core surrounded radially by a heavy-water reflector tank. Reactivity control is provided by hafnium cylinders that insert into the water annuli surrounding six of the outer fuel sites. One reactor shutdown system inserts a set of three hafnium absorbers that are normally held poised above the core by hydraulic cylinders. A second independent system initiates a partial dump of the heavy water and overrides control-system action to insert the other set of three hafnium control-system absorbers.

The MAPLE-X10 facility is under construction at CRL where it will produce short-lived radioisotopes (such as Mo-99) plus neutron-transmutation-doped silicon. At its design power of 10 MW, MAPLE-X10 will produce a peak thermal flux of 2×10^{18} $n \cdot m^{-2} \cdot s^{-1}$ in the reflector and a thermal flux of up to 4×10^{18} $n \cdot m^{-2} \cdot s^{-1}$ in a central flux trap.



Model of "ZEEP"

Current Irradiation-Research Facility Studies

After 35 years of operation, NRU needs major refurbishing if it is to continue as the national irradiation facility. Even with refurbishment, it cannot meet the requirements for accelerated aging of CANDU components. Furthermore, it is costly to operate. Accordingly, AECL Research is presently considering its options for maintaining Canada's irradiation-research capability.

A new Canadian irradiation-research facility must be able to irradiate several CANDU fuel-channel sections plus full-size bundles under realistic CANDU conditions. It must provide test facilities high fast neutron fluxes to perform accelerated CANDU-component-aging studies. To verify CANDU behaviour under severe accident conditions, the facility must test arrays of fuel pins in a horizontal fuel channel under loss-of-coolant conditions. A new neutron source will also ensure the continuation of Canada's national program in condensed-matter science.

Various options for irradiation-research facilities are under consideration. While some reliance will be placed on CANDU power reactors and available foreign facilities, some requirements can only be met by a new custom-built facility. In particular, no commercially available design can irradiate several full-diameter CANDU fuel bundles and pressure tubes in a realistic neutron spectrum without significant flux gradients and no facilities presently exist for irradiating instrumented fuel elements in a horizontal fuel channel. Accordingly, serious consideration is being given to developing the MAPLE-MTR (MAPLE Materials Test Reactor) concept which is based on the evolution of current Canadian research-reactor technology.

The MAPLE-MTR concept uses a hybrid light/heavy-water lattice to provide both a realistic irradiation environment for CANDU test loops and a region of high fast fluxes for accelerated aging studies. It will uniformly irradiate four 1-m long fuel-channel sections fueled with full-size prototype bundles under CANDU conditions. It will provide central core sites with much higher than CANDU fast-neutron fluxes for performing rapid component-aging studies. It will be able to test arrays of instrumented fuel elements in either a vertical or a horizontal fuel channel under loss-of-coolant conditions. As a new high-flux neutron source, it will facilitate the continuation of Canadian condensed-matter science.

The light-water-cooled and -moderated 19-site central core is based on the MAPLE-X10 core with the power uprated. The fuel will be plate-type, with 23 plates of varying widths in an assembly that is comparable with MAPLE-X10. To the MAPLE-X10-type heavy-water reflector tank are added various fuel assemblies to provide a coupled heavy-water lattice with test loops and fast-neutron sites similar to those of NRU. The regulating system and one shutdown system are based on MAPLE-X10 systems. A fast heavy-water dump capability provides a highly-diverse second shutdown system.

Preconceptual studies indicate that perturbed fast-neutron fluxes of about 2-2.5 $\times 10^{18}$ $n \cdot m^{-2} \cdot s^{-41}$ can be generated in the three central irradiation facilities if the central core operates at thermal powers of 20-25 MW. Each of four fast-neutron sites in the heavy-water lattice will produce fast fluxes of about 1×10^{18} $n \cdot m^{-2} \cdot s^{-1}$ in their test rigs at powers of 1.5 MW. Fresh 37-element natural-UO_2 CANDU bundles are expected to run in each of the four test loops at powers up to 900-1000 kW and peak ratings in excess of 70 $kW \cdot m^{-1}$. Assemblies of up to seven CANDU elements will run at similar peak ratings in two vertical loops and one horizontal loop in the heavy-water tank. An array of neutron-beam tubes is planned for the outer region of the heavy-water tank.

The MAPLE-MTR concept represents the continued evolution of Canadian experience with research reactors over the past fifty years. It can facilitate a future irradiation-research program similar in scale to the present program of CANDU support and neutron-science applications. Building the MAPLE-MTR facility offers a sound prospect for ensuring the necessary long-term support of CANDU reactor development and Canada's underlying nuclear-research program.

News from the Branches

Chalk River

Branch Meetings and Seminars

The 1992/93 program is in full swing and the average attendance at the meetings is about 70. A lot of the attendees are non-members and an effort is being made to encourage them to sign up. Fall schedule is listed below and planning of the winter/spring schedule is in progress.

Sept. 3	John A. Macpherson	**Education Outreach: Partnership, Possibilities and Pitfalls**
Oct. 5	Dave Lemkay	**Early History of Lumbering in Ottawa Valley**
Oct. 27	Dr. Stanley R. Hatcher	**Ethics and Atoms**
Nov. 20	Dr. Brian Stewart	**Darlington Fuel Damage Investigation**
Nov. 30	Dr. T.E. Rummery	**AECL Research: Present and Future – An Informal Discussion**
Dec. 8	Dr. A.J. Mooradian	**Physics is Immutable; Business will Adjust**

Writer's Club

The Writer's Club assisted in preparation of the CNS submission to the DSP Board. A survey of Canadian and international inquiries of nuclear energy has been prepared by J.A.L. Robertson and is being published as a special report by AECL.

Education and Public Affairs

The branch plans to continue sponsorship of the **Deep River Science Academy** and the **Education for Educators Program** coordinated by AECL. This fall the branch complied to a request from a New Brunswick teacher, Mr. Robert Coes, for help in setting up a Junior High School Science Program in Energy and Radiation. Program of seminars at **Algonquin College in Pembroke** will continue following approval of the branch budget.

M.A. Lone

Ottawa

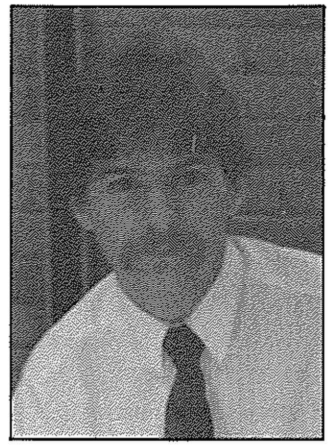
Two meetings were held this fall by the Ottawa branch of the CNS.

The first involved a visit, in October, to the federal Government Emergency Operations Co-ordination Centre. Members were given an overview of the operation of the Centre by Director Paul Renault and then toured the facility. The Centre is the focus and communications centre for all federal government departments in responding to emergencies.

On December 3, Andrew Stirling, general manager of AECL Accelerators business unit, described, with the use of many excellent slides, the installation of the first commercial IMPELA accelerator in New Jersey, USA, and discussed the difficulties of taking complex technology from the laboratory to a successful commercial product.

The program for 1993 has not yet been finalized.

Golden Horseshoe



Glen Havel, co-chair Golden Horseshoe Branch

The Golden Horseshoe branch, based in Hamilton, has been re-vitalized this fall under co-chairs Glen Havel and Jeremy Whitlock, both graduate students at McMaster University.

The branch co-sponsored, with McMaster University's Dept. of Engineering Physics, a trip to Darlington NGS on November 3. About 25 people, one third being undergraduate nuclear engineering students, took part in this event. Darlington has been a particularly fascinating station to visit because of the public access permitted around reactors under construction, but this period will end with the hot commissioning of Unit 4. Fortunately, our timing was perfect and our group was able to tour the Unit 4 vault.

The following day, November 4, a branch public seminar was held at McMaster University, where Fred Dermarkar, a reactor physicist at Darlington, gave a presentation on the Darlington N-12 fuelling problem. Mr. Dermarkar loaned us his copy of an Ontario Hydro video on the investigation program, and this will be shown to interested members and others in a lunch hour viewing some time in the near future.

The branch has also recently established an information library at McMaster University in the Nuclear Research Bldg., which contains technical and public relations material on the Canadian nuclear industry.

Jeremy Whitlock

Saskatchewan

The new branch executive for 1992/93 was confirmed at the 1992 September 30 branch meeting as follows:

D. Malcolm	Chairman
D. Goertzen	Vice-Chairman
M. Hollingsworth	Treasurer
J. McMahon	Secretary
A. Dagher	Councillor – Membership
S. Webster	Councillor – CNS Education Fund Prizes
L. Christie	Councillor – Programs

Planning for the 1992/93 activities is in progress, and the program is expected to be similar to the very successful 1991/92 program in content and format.

Branch members have been extremely busy with information activities leading to the NDP policy convention. The success in getting the resolution passed to re-negotiate an arrangement with AECL for pursuing nuclear energy related activities in Saskatchewan is due in no small measure to the efforts of Saskatchewan CNS Branch members. We congratulate them on their successful efforts!

The expected agreement between the Saskatchewan government, the federal government, and AECL could have a large positive impact on the Canadian Nuclear Industry.

Manitoba

A newsletter and questionnaire is being prepared for distribution to members of the Manitoba branch to solicit interest and ideas for branch activities. It is planned to hold a general meeting in January to elect a new slatc of officers, and it is anticipated that the program of activities will include educational activities such as student awards, meeting with teachers, etc.

Toronto

The society's most active branch, Toronto, has continued its popular "Public Presentation Series" this fall:

Sept. 30	Ken Talbot	**Restoring Performance at Bruce 'A' NGS**
Oct. 27	Marion Fraser	**The Case for Demand Management**
Nov. 24	Dan Meneley	**Improving RBMK Safety**

The essence of Ken Talbot's talk was covered in an article in the summer 1992 issue of CNS *Bulletin*. Ric Fluke's review of Marion Fraser's address on Demand Management is included in this issue, as is the basic text of Meneley's talk.

The new Branch Executive for 1992/93 are:

Lisa Anzil	Chairperson
Greg Evans	Vice-Chair
Stephen Rogers	Treasurer
Joel Almon	Secretary
Shayne Smith	Past-Chair
Keith Weaver	Public Affairs
Raymond Quan	Student Affairs
Ben Rouben	
Gord Sullivan	

CNA/CNS Community Outreach Program

All CNS members should have received letters from president Bill Midvidy, seeking their participation in the Community Outreach Program being launched by the Canadian Nuclear Association and the Canadian Nuclear Society.

As of early November, 115 CNS members have indicated their willingness to join the program and meet with different groups.

The Community Outreach Program is primarily a consensus-building exercise, with emphasis on listening to and understanding the concerns of the people in the groups involved. Initial trials will be conducted in early 1992.

It is not too late to join the program. If you are interested, or just want more information, contact Bill Midvidy at 416-592-5543.

Council offers to confer with Minister

Ed. note: *At its 25 November 1992 meeting the CNS Council approved an approach to the Ontario Minister of the Environment proposed by Jerry Cuttler, to try to develop a dialogue with her and her staff. The initiative was prompted by Jerry's attendance at at a large education and environment conference held in Toronto in late October and his concern about the tone of the papers and discussion.*

Following is the text of the letter to Ruth Grier, Ontario Minister of the Environment that was sent in early December.

Jerry Cuttler

The Hon. Ruth Grier
Ontario Minister of the Environment

RE: Cooperation on Education Programs on Environmental Concerns

Dear Ms. Grier,

I am writing on behalf of the Canadian Nuclear Society (CNS) to explore the possibility of opening a proactive dialogue with your ministry (and the Ontario Government) on energy and environmental issues. We are aware of the New Energy Directions policy that puts conservation, renewable energy and small power generation ahead of the nuclear option.

The Canadian Nuclear Society consists of 800 Canadian scientists, engineers and other professionals. More than 75 per cent of our members live and work in Ontario. The principal objectives of the Society are to act as a forum for the exchange of information relating to nuclear science and technology, and to foster development and utilization of this technology for peaceful uses, such as generation of electricity, nuclear medicine, preservation of food, etc.

The CNS is concerned about the declining interest in science and math in our schools and the declining enrolment in science and technology-related programs at the college and university levels. Ontario will need a continuing supply of scientists, engineers, technicians and technologists.

I attended the ECO-ED World Congress for Education and Communication on Environment and Development, held October 16-20 in Toronto. I was very impressed with the feelings expressed by many of the 3000 delegates (from 64 countries) about the present and potential impact of world development on the environment. They are committed to educating the coming generation about the need to change our present lifestyle to achieve sustainable development.

The CNS would like to support and participate in such programs because our members share these concerns and have access to relevant technologies. For example, the use of nuclear energy to supply more than 50 per cent of Ontario's electricity needs has helped Ontario control the escalation of atmospheric pollution. This technology, along with renewable sources of energy, can help reduce the combustion of fossil fuels in the developed world, and supply the increasing demand for energy in developing countries as they progressively attain a reasonable standard of living.

Over the past forty years, our nuclear scientists and engineers have taken exceptional care to develop and manage technologies that ensure worker and public safety. The Pickering Nuclear Generating Station has just completed 20 years of safe operation. The release of hazardous substances to the environment is very low and is carefully monitored and controlled. (Releases of radioactivity are typically below 1 per cent of permissible limits.) The nuclear industry already has satisfactory methods for storing used fuel, and their technology for disposal will soon be undergoing a public environmental review in the appropriate manner.

At ECO-ED, I listened to the address by Mr. Frederico Mayor, Director-General of UNESCO, entitled "Education for Sustainable Development: Taking Up the Challenge of Rio." He identified four main challenges concerning education for sustainable development (ESD). The third challenge pertains to the quality of the information received. *"All too often this information is scientifically inaccurate, out of date or biased towards a particular disciplinary, national, regional or cultural point of view. Teachers, journalists and other educator/communicators need to draw on the best available knowledge, which is often located in the research community and within industry with which they have little direct interaction. Much more needs to be done to ensure that scientifically sound information reaches those responsible for its communication to the public at large."*

In this regard, the multi-disciplinary Canadian Nuclear Society would like to volunteer assistance in providing scientifically accurate information to teachers on nuclear technology and other technologies affecting sustainable development. We would also like to identify what we must do or how we must change to establish friendly relationships of cooperation and trust with the Government of Ontario.

The Canadian Nuclear Society would like to meet with your ministry to discuss these matters and how we could work together on other environmental issues.

Yours truly,

J.M. Cuttler, DSc, PEng
Treasurer

News of Members

George Fanjoy, long-time head of Central Nuclear Services at Ontario Hydro, retired last summer. George began his nuclear career with the NPD team at Canadian General Electric in the late 1950s before joining Ontario Hydro's nuclear operations group.

Larry Woodhead, another long-term member of Ontario Hydro's nuclear team, retired in September 1992. For many years Larry was Director of Nuclear Operations at Ontario Hydro. He was one of the original operations team at NPD and subsequently oversaw the commissioning of Pickering "A" where he became the first superintendent (station manager).

Bob Jervis retired last summer as professor in the Department of Chemical Engineering and Applied Chemistry at the University of Toronto, but will continue as professor emeritus. He is known world-wide for his work on neutron activation. Dr. Jervis is chairman of the Advisory Committee on Nuclear Safety of the Atomic Energy Control Board.

Nuclear Energy in the 21st Century

A Statement by the International Nuclear Societies Council

Ed. Note: *At its meeting, 15 November 1992, in Chicago, the International Nuclear Societies Council approved the following statement for publication in the many countries represented by the member societies. The idea of such a statement was advanced a year ago and serious drafting began at the INSC meeting in Taiwan in April 1992. The INSC was formally established in 1990 by learned nuclear societies from North America, Central and South America, Europe, and East Asia, after several years of informal consultations. The societies of INSC have a total membership of over 40,000. Former CNS president Ken Talbot is the CNS representative on INSC and had a major role in the drafting of the following statement.*

A Sustainable Energy Resource

There is a growing global consensus on the need for sustainable development. Adequate energy supply is critical for emerging economies to develop and for industrialized economies to support the legitimate needs of their societies. Energy in the form of electric power is essential to improve efficiency, develop conservation techniques, recover, recycle and properly dispose of wastes, and minimize environmental pollution. Nuclear energy can play a vitally needed role in meeting future electricity needs.

Safety and Environmental Assessment

Electricity generated from nuclear fission energy has been evaluated in more depth than any other energy source. Licensed nuclear power plants, designed to established standards and operated by qualified personnel, have amassed a safety record unmatched by any alternative energy source. The accident at Chernobyl was indeed serious. Important safety features required by Western safety standards, including a pressure-resistant containment building, are not present in the Chernobyl-type plants. All new designs must meet stringent safety standards, and international efforts are proving successful in instilling a safety culture and management controls to all operating plants.

With the exception of those regions where more hydroelectric power is available, nuclear energy is the only large-scale source of base-load power that produce no sulfur oxides, no acid rain and no carbon dioxide emissions. It does produce radioactive wastes. These are sufficiently concentrated that it is worth the effort and cost to confine them and dispose of them in permanent repositories, and thereby keep them out of the environment forever.

Wastes already exist from more than thirty years of commercial nuclear electricity production. The technology for safe disposal is well understood, and is being pursued in a number of nations. High-level wastes are concentrated, carefully handled, and are being stored safely. The major nuclear nations have plans for permanent disposal facilities. It is the obligation of the current generation to dispose of them safely and permanently. The proper test for any repository is safety, and not its location relative to state or national borders.

A Part of the Mix for Base-Load Electricity Production

No claims are made that nuclear power is the only answer to electricity needs. Nuclear plants provide base-load power, day and night, while peak loads can be met by natural gas and even oil. Alternative energy sources: solar, wind, geothermal and hydro, should be used whenever they are available. Choices for future plants need to be based not only on the cost of production, but also on environmental impacts. In some nations, attempts are being made to estimate and internalize environmental costs into the calculated costs of production.

Energy conservation programs can lower demand growth rates, and delay for a few years perhaps, but not eliminate, the need for new power plants.

The record around the world shows that nuclear plants can compete effectively with coal and other alternative sources. They provide diversity of supply, and in some nations are of critical importance in reducing the need for imported oil and liquefied natural gas. Reliability records are improving each year. New plants are currently under construction in France, Japan, China, Korea, Taiwan, Brazil and Romania.

Uranium resources are abundant and fuel supplies are economical at this time. Recycling of plutonium will help to keep nuclear fuel prices down and extend the natural uranium resource well into the 21st century. Ultimately, breeder reactors will be able to produce enough new plutonium to assure sufficient nuclear fuel supply for future centuries.

The Civilian Nuclear Power Fuel Cycle and Safeguards

The commercial nuclear electric power fuel cycle is not a logical or effective pathway to nuclear weapons. Systems of safeguards under International Atomic Energy Agency (IAEA) agreements have proven successful in assuring that diversion of plutonium has not taken place. Experience has shown that accurate inventories of critical materials can be maintained.

The major weapons states are IAEA signatories and have put their commercial fuel cycles under IAEA safeguards. Most non-weapons states have accepted full-scope safeguards, committing themselves to having no national program to develop nuclear weapons. It is of critical importance to bring the remaining nations into IAEA agreements.

The sad experience with Iraq proves that if a nation is determined to acquire nuclear weapons, it will not depend on the nuclear power fuel cycle. Iraq's weapons facilities were totally clandestine. It had no nuclear power plants.

Summary

Nuclear energy is a safe and environmentally acceptable source for base-load electricity generation. Because radioactive wastes already exist, facilities must be built for their ultimate disposal. Commercial nuclear power under IAEA safeguards is not a realistic pathway to nuclear weapons. Therefore, decisions affecting the extent of nuclear power's future role will likely depend on economics, diversity of fuel supply and environmental considerations.

Electricity will help build a clean energy base upon which sustainable future development will be based. As other energy sources become practical, they can join fossil fuels and nuclear energy to sustain a diverse base of energy supply for the future.

AECB President Retires

Dr. René J.A. Lévesque has announced his retirement as President of the Atomic Energy Control Board effective 2 January 1993.

Since his appointment in September 1987, he has seen the agency through profound changes. During those years the AECB's staff increased by 50%, made possible by the government's move to cost recovery.

Dr. Lévesque was especially interested in making the AECB more open and accessible to the public. With this goal in mind he presided over several Board meetings and public information sessions in communities near nuclear facilities.

His term of office saw a number of initiatives. In 1990 the AECB adopted a cost-recovery program in accordance with government policy. Proposed new radiation dose limits were announced and a program of public consultation undertaken.

On the international level, Dr. Lévesque concluded a number of bilateral agreements with nuclear regulatory bodies in several European countries and with the USNRC for the exchange of information. In 1991 the AECB established a training centre to provide technical assistance to foreign nuclear regulatory agencies involved with nuclear equipment of Canadian origin.

The president of the AECB is appointed by Cabinet.

Money and Class in America

Lewis H. Lapham, Ballantine, New York, 1989 (ppbk).

Reviewed by Keith Weaver

On the face of it, this book has little or nothing to do with the Canadian nuclear scene. Being a story about (or rather a consistent set of "notes" on) personal life and politics in the U.S., it could be easily discounted, except for three significant reasons to the contrary.

First, the old perennial reason. Whatever the advantages or disadvantages, and whatever one is inclined to think about it, our proximity in Canada to the U.S. and its powerful influence on practically everything we do means that we ignore, at our peril, any informed commentary on the state of the republic that clings to our southern boundary. Hence, the first implicit judgmental statement on this book: it is an important and informed social commentary.

Second, one of the main points of focus throughout the book is the anatomy of the ruling paradigms in American corporations and business, and how these in turn affect and draw sustenance from personal attitudes. The significance of all this is that big corporations are a major fact in everyone's life. Even if a "better" world without these corporations could be constructed, it couldn't be done by tomorrow, or next decade. The attitudes that such corporations may help to foster in ordinary people, and possibly most important, the attitudes of those people who direct the corporations, can be a major determinant on the direction taken by the whole society. Anything that can provide insight into this very complex nexus makes our most valuable precious metals look like used drilling mud.

Third, but by no means insignificant, is the refreshing and modish literary garb that clothes these Notes. The tub thumpers, the TV evangelists, the purveyors of snake oils, of panaceas, of arguments and case studies presented with clammy and equally reptilian logic, these all corner more than enough ink and air time. To have a different view expressed with wit, grace and any number of clever literary devices, is at least as delightful as it is valuable. In short, the book is extraordinarily well-written, and thoroughly enjoyable.

To try to summarize in a short space, Lapham explores the nature and consequences of what he refers to as the American civil religion: the veneration of money. The sacraments of this religion are the most pathological activities associated with the acquisition of money and the ostentation attendent upon its possession in quantity. These rituals exert a terrible human toll in terms of people becoming intellectually and socially stunted, and this is made clear by some of the chapter headings which Lapham has selected: The Romance of Crime, Social Hygiene, Descent Into The Mirror, Holy Dread, Coined Souls. Throughout the book, Lapham illustrates aspects of this main theme by way of anecdotes or recounted instances of situations, people's behaviour, etc. The stories Lapham sets out range from funny, through trivial and tedious, to sad, disturbing, and horrifying. It is these rather loosely connected stories, and the nature of their telling, that contain the real ore to be mined from the book. Lavish and luxurious use is made of hyperbole, cutting wit, pathos and some superb imagery. Metaphors infiltrate the text by the regiment. People don't just retreat from an unwelcome guest; they lumber off into the library like a stunned wildebeest. (Indeed, the one criticism that might be levelled against the book arises from the uncomfortable feeling that these descriptions sometimes go beyond the bounds of poetic license and reasonable hyperbole, that the description sometimes introduces a systematic distortion, and that perhaps there is some considerable glee that accompanies the distorting.) Toward the end of the book, Lapham presents a telling summary of a society driven to protect property and privilege by the people who enjoy those goods. This becomes identified as the *de facto* definition of conservatism, as opposed to its deeper nature as a cast of mind, a cautious overall approach to life based primarily on successful past practices.

This brings one to a somewhat more immediate aspect of the book. Lapham is a liberal. Just to stop and think about this term for a moment (or "conservative" or "socialist" for that matter) makes it clear that these words have all but ceased to have everyday meaning. "Liberal," for instance, might be recognized as a noun which transmogrifies into an object of contempt after combining with the modifier "bleeding heart;" on the other hand, it may unite with the substantive "democracy," thereby giving rise to a thing of transcendent beauty. "Socialist" has become something of a bad word in almost all quarters. The irrational nature of this process, even among people who are clearly intelligent, has been demonstrated often enough. (An almost imperfect example of this can be found in the book "The Trouble With Canada" by William Gairdner. At one point, Gairdner presents a faultless description of the classic "conservative" and "liberal," i.e. the original best meanings of those terms. However, when he comes to "socialist," a term every bit as interesting and important as the other two, the text degenerates into a rant.)

It is probably true that the details of Lapham's critique apply only to the U.S. That doesn't mean that everyone else can sit around and chuckle smugly. The danger he points out is clear and present on many fronts. The widespread occurrence of mental rigidity, a willingness to accept dogma and slogans at face value, total fixation on a narrowly defined objective, could lead, in any political context, to distorted and ineffective government, intransigent bureaucracies, faltering corporations and a fragmented, dispirited society. Because of the fundamental societal importance of healthy corporations, it is there, probably even more than in individual personal life, that commentaries such as Lapham's have the greatest potential value.

Calendar

1993

January 27-29 **Probabilistic Safety Assessment for 1993**
Clearwater Beach, Florida
contact: Mark Averett
St. Petersburg, Florida
Tel.: 310-825-1300

February 9 **CNA/CNS Nuclear Energy Winter Seminar**
Ottawa, Ontario
contact: T. Wigley
CNA
Tel.: 416-977-6152
Fax: 416-979-8356

March ? **Seminar on Acoustic Vibrations and Pressure Pulsing in Rotating Machinery**
Toronto, Ontario
contact: A. Kumar
AECL-CANDU
Tel.: 416-823-9040
Fax: 416-823-8006

April 2-3 **CNA/CNS Student Conference**
École Polytechnique, Montréal, Québec
contact: Dr. D. Rozon
Tel.: 514-340-4803

April 20-21 **CANDU Reactor Safety Course**
Toronto, Ontario
contact: Joel Almon
Ontario Hydro
Tel.: 416-506-6889

June 2-4 **4th International Conference on Simulation Methods in Nuclear Engineering**
Montreal, Quebec
contact: A.F. Oliva
Ontario Hydro
Tel.: 416-592-7676

June 20-24 **ANS Annual Meeting**
San Diego, California
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

June 22-24 **Annual Conference: Canadian Radiation Protection Association**
Toronto, Ontario
contact: Shirley Coyne
Tel.: 416-683-7516

September 5-11 **International Conference on Nuclear Waste Management and Environmental Remediation**
Prague, Czechoslovakia
contact: Radovan Kahout
Ontario Hydro
Tel.: 416-592-5384

September 13-14 **International Conference on Expanded and Rolled Joint Technology**
Toronto, Ontario
contact: G. Kharshafdjian
AECL-CANDU
Tel.: 416-823-9040, Ext. 2102
Fax: 416-823-8006

September 12-16 **Future Nuclear Systems: Emerging Fuel Cycles and Waste Disposal Options**
Seattle, Washington
contact: Alan Walter
Richland, Washington
Tel.: 509-376-5514
Fax: 509-376-6282

September 20-24 **7th International Conference on Emerging Nuclear Energy Systems**
Makuhari, Japan
contact: Dr. T. Hiraoka
Japan Atomic Energy Research Institute
Tokai-mura, Japan
Tel.: 81-292-82-5517
Fax: 81-292-82-6122

October 3-8 **International Nuclear Congress – INC '93**
Toronto, Ontario
contact: Dr. Ben Rouben
AECL-CANDU
Tel.: 416-823-9040
Fax: 416-823-8006

November 14-19 **ANS Winter Meeting**
San Francisco, California
contact: Dr. W.I. Midvidy
Ontario Hydro
Tel.: 416-592-5543
Fax: 416-978-0193

1994

May 1-6 **9th Pacific Basin Nuclear Conference**
Sydney, Australia
contact: 9PBNC Conference Secretariat
Fax INT 61-6-273-2918

October 19-21 **3rd International Containment Conference**
Toronto, Ontario
contact: D. Pendergast
AECL-CANDU
Tel: 416-823-9040
Fax: 416-823-8006

Canadian Nuclear Society

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- ☐ SASKATCHEWAN
- ☐ TORONTO
- ☐ CENTRAL LAKE ONTARIO (Pickering, Darlington, Port Hope, Peterborough)
- ☐ USA AND INTERNATIONAL

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† New members joining after 1992 September 1st will be members for 1993. Fee includes GST.

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- ☐ TORONTO
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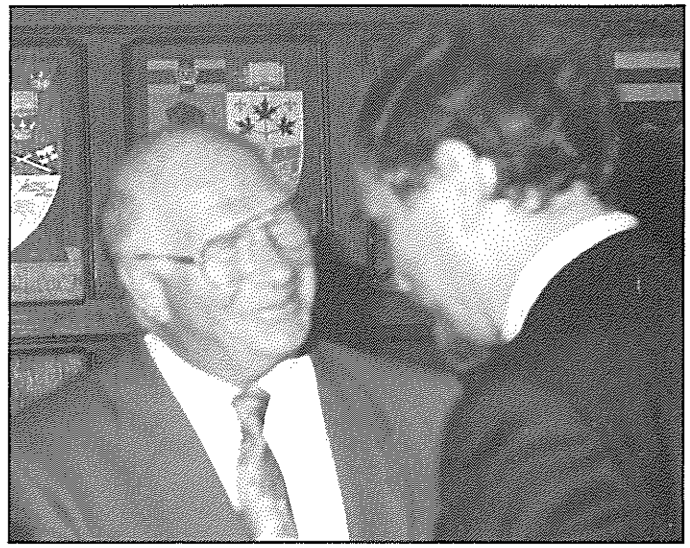
Jervis receives Russian award

During the 2nd International Conference on Nuclear Analytical Chemistry held in Toronto in June 1992, Prof. Robert E. Jervis of the University of Toronto was awarded the Timofeev-Ressovsky Medal. That medal is awarded by the Russian Academy of Medical Sciences and the Russian Association of Radiological Problems in memory of Nikolay V. Timofeev-Ressovsky, a prominent Russian scientist who was a founder of radiation genetics, radiation biology and radiation biogeocenology. The medal is given for outstanding achievement in the fields of radiation genetics, radiation biology, evolution doctrine, environmental protection, and mankind survival.

Earlier that month the Canadian Society for Chemistry held a R.E. Jervis Symposium on Neutron Activation Analysis in Edmonton. In 1991, Dr. Jervis was the honorary chairman of the 2nd International Conference on Methods and Applications of Radioanalytical Chemistry in Hawaii which was co-sponsored by the Canadian Nuclear Society.

A number of Dr. Jervis' former students have proposed the creation of a Jervis Award for outstanding work in radiochemistry, possibly to be awarded through the CNS.



Ye. Zaichik, of the Russian Academy of Science, presents the Timofeev-Ressovsky Medal to Bob Jervis during the 2nd International Conference on Nuclear Analytical Chemistry in Toronto, June 1992