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FOREWORD

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SESSION 1

JOINT CNA-CNS PLENARY

SESSION CHAIRMAN

Charles F. Baird
New Brunswick Power Corporation
NUCLEAR POWER: A PLACE IN CANADA'S FUTURE?

F. Kenneth Hare

Notes for keynote address, Canadian Nuclear Association, Saint John, N.B., June 8, 1992

Mr. Chairman, Ladies & Gentlemen:

I am grateful for the opportunity — and honour — of opening the technical discussions at CNA's annual bash. I shall begin with some apologies; go on to speak the truth as I see it; offer some advice — and then beat a hasty retreat westward. An opening speaker has two great blessings: he or she can be qualitative, and escape from the need to crunch and spit out numbers; and he or she can express opinions. I am making full use of both privileges.

The apologies first. Through no plan of my own I have twice played the rôle of officially-appointed snooper into this industry's affairs. In early 1977 Alastair Gillespie, then Minister of Energy, Mines and Resources, and his Deputy, Gordon MacNabb, asked me to chair a quick (and inevitably dirty) look at nuclear waste disposal in Canada. My colleagues were the late Jim Harrison and Archie Aikin, whom you must mostly know. Our report, which went to Alastair a day early, on August 30th, 1977, was hastily prepared. But AECL and Ontario Hydro have subsequently acted so well on our advice that Canada now appears among the world's leaders in intermediate storage and final disposal technology.

Then David Peterson and his Cabinet appointed me as sole Commissioner of the Ontario Nuclear Safety Review in 1986-88, in the wake of Chernobyl. Currently I serve as Chair of the Technical Advisory Panel on Nuclear Safety of Ontario Hydro (TAPNS), and as a member of the Technical Advisory Committee of AECL Research; so I'm still there, peering over the fence -- not, in my case, an exclusion fence.

I want to make five points about this personal record:

First — I have always insisted that I act independently, with no instructions from anyone in the industry, government, or interest groups.

Second — This independence has been consistently respected by the industry representatives and public servants with whom I and my colleagues have dealt, even when our findings were against what they saw as their best interests.
Third - I have had freedom of access to all sites, and all documents of which I have knowledge.

Fourth - I have relied on numerous consultants, not least your President, to train me, a clueless outsider, in the technical aspects of the industry.

Fifth - And finally, my concern has been for the safety of the public, and of the exposed workforce of the power-producing utilities; I have had no experience at the mining and refining ends, and only a little in the research phase.

When I began these studies I was sceptical as to the safety of nuclear technology. As far as power-production was concerned, I thought that the trouble lay partly up front, in the mine tailings problems, and as regards the safety of underground miners; and partly at the back-end, in the disposal of spent fuel, or of high level processing wastes. I distinctly remember telling my students that waste-disposal was the Achilles Heel of the nuclear industry. I gave little thought to reactor safety.

But fifteen years of exposure, in which I have been given unrivalled access to the industry's inner workings, have changed my view. I now see waste disposal as a straightforward task needing technical care and foresight, but not presenting insuperable difficulties. The AECL-Ontario Hydro proposals being subjected to federal environment assessment (under the eye of my friend Blair Seaborn) will protect this and subsequent generations against any credible hazard. Much of the public comment in this area is science fiction.

On the other hand, I may have underestimated the problem of reactor safety. It was operational reactor failure that led to the accidents at Sellafield (then called Windscale, and not a power reactor), Three Mile Island and Chernobyl. We have not been immune in Canada; the NRX and NRU events at Chalk River remind us of that. And CANDU reactors, under operational conditions, are not immune from failure. Their excellent defences in depth have protected workers and public alike. But I have spent a lot of time since Chernobyl looking at these reactors, to get some measure of the level of safety achieved.

The long-term future for nuclear power -- and this is my thrust today -- depends in all industrialized countries on answers to a short series of tough questions:

1. - can the power utilities maintain their present standards of safe performance; and, in some cases, can the standards be improved?

2. - can the body politic be persuaded that these standards are adequate?
3. - can the costs of safe design, construction, operation, waste disposal and decommissioning be kept sufficiently low to maintain nuclear power's competitive edge, if properly reckoned?

4. - and can international safeguard programs prevent the diversion of skills and materials into military misuse, even in rogue countries that notoriously disregard the Non-Proliferation Treaty?

My personal experience bears on the first and second of these questions, and most of my remarks will deal with reactor safety and its measurement. But of course I have thought, read and talked about the others. I shall later offer some comments on them, speaking as a citizen rather than as an official snooper.

Let me turn first to safety performance. What can be said about it?

As regards events within Canada, since the accidents in the research reactors at Chalk River, there has been no event that has endangered the public, although within the CANDU plants there have been significant failures that increased the radiological risk to the workforce. Normal operation has exposed neither the workforce nor the public beyond the Atomic Energy Control Board's limits; in fact the operational target of not exceeding 1 per cent of those limits has almost always been reached or bettered.

It is important to keep check on this foursome of situations; one must consider workforce and public safety separately, and how both may fare in accident and normal conditions. The study of twenty years of power reactor operation enabled the Ontario Nuclear Safety Review to confirm that all four combinations have yielded reassuring answers. I believe this still to be true as regards safety.

The proof of the pudding must be in the eating. We have had no severe accident, so we can apply this rule only to overall operational experience. The measure must be the exposure, health and mortality statistics of the relevant groups, and these have now accumulated to the point where one can make some generalizations:

(i) The exposed Canadian reactor workforces appear to have suffered little or no detriment from working within the reactor buildings. Average occupational exposures in the largest utility, Ontario Hydro, are now well below world average occupational values, and far below the AECB limits and International Commission on Radiological Protection recommendations. Mortality from cancer of all kinds among the Ontario Hydro workforce over the years 1971-1989 was only 66 per cent of that of the equivalent group in the general Ontario
public -- in spite of at least double overall exposure. AECL's experience has also been excellent.

(ii) Releases of radioisotopes (chiefly tritium, carbon-14, noble gases and certain particulates) from venting and cooling systems of CANDU reactors have been kept on an annual basis within or below 1 per cent of the permitted limits at all stations, though there have been brief episodes of higher tritium release following heavy water spills.

(iii) There is no comprehensive monitoring of public exposure as the result of these releases, but AECB-sponsored epidemiological analyses of children born or resident near Pickering NGS and Bruce NPD have shown slightly (but not significantly) elevated mortalities from leukemia, and in the case of Pickering NGS a significantly elevated incidence of Down syndrome. In the latter case, a similar excess occurred in eastern Ontario, far from any reactor. These clusters of cases are unlikely to have been due to the small releases from the reactors; but they have been given much publicity, and raised public concern. The same is true of rumours concerning Gentilly-II in Quebec, which have been shown to be unfounded.

The overall health and safety record in Canada is thus good, though a more targeted form of epidemiological survey is needed to eliminate any doubts about leukemia and Down syndrome incidence near the Ontario reactors. Epidemiological and medical standards alone do not justify such attention, since there is no evidence of excess exposure to radiation, but public concern does -- and should be catered to, in my own judgement.

The care with which this monitoring and research effort is conducted is praiseworthy, and the results convincing to people who take the trouble to read them. Scientists from the National Cancer Institute, the Ontario Cancer Treatment and Research Foundation, and the Faculties of Medicine of the Universities of British Columbia and Toronto are involved in the programs. The industry is sometimes accused of cooking the books, but no reasonable citizen can suspect some of the country's leading cancer agencies of doing so.

On the down side, I have heard responsible people remark that all this attention to health effects must mean that the industry expects an adverse impact. People find it hard to believe that public corporations -- and all our nuclear operators are just that, agents of public policy -- can behave responsibly.

The damage done to public opinion by the Chernobyl disaster was enormous. My own appointment as Commissioner of the ONSR arose
directly from the event, and my Review's findings that no accident of this sort could occur in a CANDU reactor was scoffed at by some commentators. On the other hand, the very remote possibility of other forms of severe accident in a CANDU, mentioned in the ONSR report, was seen as an over-optimistic bit of window-dressing.

In the same way, the assessments of the consequences of Chernobyl by IAEA and other bodies have been written-off as white-washing, while claims of heavy casualties and impending cancer deaths continue to be widely circulated, not least by officials in Belorus and Ukraine. The reality was bad enough; the imagined consequences are far worse. I see no sign as yet that public opinion has shifted towards the more sober views that I am sure reflect the truth.

Chernobyl is not alone in casting doubt on Canada's seemingly sound performance. I have just spoken of the evidence of good health and low cancer mortality of the Canadian exposed workforce. I also spoke of the probably accidental clustering of leukemia and Down syndrome incidence near certain Canadian reactors. Speculation about both results has been prompted by several foreign studies. In the United Kingdom, for example, elevated mortalities from childhood leukemia have been reported near the Sellafield, Aldermaston and Dounreay nuclear complexes. Martin Gardner's hypothesis that the Sellafield cluster might be due to pre-conception exposure of fathers to ionizing radiation has been widely reported.

Most recently, findings of a significant dose-response relation for leukemia incidence among exposed British workers have led to questions about the excellent record among Canadian workers (even though the overall proneness of the British group was still below that of the public at large). Much less attention has been devoted to optimistic findings about French workers, due to Catherine Hill and Agnès Laplanche, and to the giant Jablon et al. U.S. National Cancer Institute study, which involved almost a million exposed workers -- without finding any evidence of adverse effects. In this field, only bad news gets media attention; and Canada's highly responsible watchdogs get little credit for their high standards of worker and public protection.

Also crucial to the future of the power utilities is the regulatory process. The Atomic Energy Control Board provides, under federal statute, a thorough and competent system of regulation. Its resources are being progressively augmented, and the vigilance with which it inspects the operating reactors has much increased. The system is, as you must all know, one that has European roots, rather than American; the AECB declares the standards that have to be maintained, and the operators have to devise ways of meeting those standards. Subsequently they must demonstrate compliance, and the AECB scrutinizes that compliance with increasing rigour, on an arms-length basis. The entire
I remain strongly opposed to a prescriptive approach to regulation. It is becoming increasingly difficult, however, to maintain this position. In software quality assessment, for example, it is difficult for the AECB to avoid critical scrutiny that does not involve suggested redesign of the software. Intricate technical systems of all kinds present dilemmas of this kind; Star Wars was, and is, a glaring example. But I am confident that the tensions now in the air can be relaxed, because we have some of the best talent in the world at work on both sides of the regulatory boundary.

We have to see regulation through international spectacles, too. The shocking condition of the industrial equipment in eastern Europe and in the C.I.S. became apparent as the diplomatic thaw proceeded. Already the IAEA has moved towards a set of standards against which an upgrading of the region's reactors can be judged, and some Canadian individuals and members of this Association are already involved in the process. I welcome this, because failures of reactors anywhere in the world affect opinion about the generic safety of the technology; and if the accident is severe enough, as at Chernobyl, radioisotopes may be spread hemisphere-wide. We all have a large stake in what happens east of the old Iron Curtain.

Let me now turn to costs. If nuclear technology did not require heavy investment in safe design, construction and operation, it would unquestionably be the cheapest source of large-scale power. No doubt this is why the Soviet Union's RBMK reactors appear to western eyes to be so poorly designed. But western reactor design, and especially that of CANDU, with its need for fast shutdown systems, requires a huge investment in massive concrete containments, expensive control, monitoring and back-up systems, and elaborate operator training. Hence initial costs are high; moreover, a large, but unspecified, part of the total is incurred by the installation of safety systems. Moreover, these expenditures are needed to protect not only the workers and public, but the equipment itself. Three Mile Island, for example, appears to have hurt no-one; but it involved the write-off of an entire reactor, and huge expenditures on clean-up measures.

Canadian reactors pose this question inescapably. Because a large loss-of-coolant accident can induce a rapid power transient, engineers have had to build super-efficient high-pressure heat transport systems, which are needed in any case to generate electric power. But they have also had to design and build costly emergency core cooling systems, strong containments and the impressive vacuum buildings that are unique to Ontario's multiple-unit stations. All these stand idle unless and until a loss-of-coolant occurs. The necessary review processes are slow and, in my eyes, cumbersome. This adds to the cost.
Canadian thinking about these high costs, and expert judgements about their acceptability, have assumed high capacity factors — which in turn have depended on reliable full-power refuelling, and good performance by all process and safety systems. Point Lepreau, N.B., has fully justified these high hopes. Since its commissioning nine years ago it has achieved a capacity factor of 94 per cent, a figure that puts it at the top of the world league. But other CANDU reactors, especially older units, have had many recent problems. Pressure tube failures have led to costly replacement programs and shutdowns of entire units. Problems of availability have also occurred in emergency core cooling systems and containment. These stand-by systems have suffered from failures of conventional equipment, having nothing to do with nuclear technology itself. A higher level of preventive maintenance should have been in place in the early years of CANDU operation. All these failures have added substantially to the real cost of CANDU-generated electricity. I am not equipped to calculate by how much.

It is obvious, therefore, that tighter maintenance standards, and a higher reliability level of all components, are needed if capacity factors are to be maintained at economically sound levels. And clearly the search for tighter operating standards must include attention to the human factor. In spite of training programs that are widely admired outside the country, Canada still witnesses lapses of operational judgement and, in all justice, of brilliant performance when failures occur. It would be nice if Canadians could feel that the maintenance crews on their stations were in what Maytag claims is the fate of its washing-machine staff: that they are bored-stiff at having so little to do! Canada is unfortunately far from that situation.

This question is not just economic. Of course rising costs weaken the case for future nuclear development. But there is also the safety question. I and my colleagues have seen no threat to public safety in recent CANDU performance. But I agree with those who say, as does my friend and mentor, Archie Robertson, that failures in process systems (which incur revenue losses as well as repair costs) imply that comparable failures might occur in safety systems that would be needed if a severe accident ever did strike one of our reactors. High capacity factors are -- or ought to be -- evidence of a healthy and well-maintained system, in which the public's interest in low power costs can be accompanied by confidence that the system is being safely operated.

* * * * *

Listening to myself talk, I seem to have concluded that the industry has done a pretty good job in protecting health and safety, but is now facing a worrying need to update -- at high cost -- the older power reactors.
That is not at all the conclusion reached long ago by the anti-nuclear activists, whose views have carried the day with at least two provincial governments, including that which controls most of the country's reactors. Nor is it the view conveyed by the industry-sponsored television commercials, which convey an impossibly soothing image that in my view is a quite unsuitable message to convey to the public that actually owns the reactors. The situation in the U.S. and in some European countries, is even less encouraging to the believers in nuclear power -- of whom I am one.

The usefulness of nuclear fission as the prime source of our electrical base load, at least in certain provinces, ought to depend on a dispassionate analysis of its merits and failures. I have tried, over a decade and a half, to apply this rule to the question of safety. I believe I have been able, with much help from others more expert than I, to influence the way in which matters are being handled in the utilities, in the nuclear generating stations, and by the Atomic Energy Control Board. The industry and its regulators, that is to say, have listened to what I have said, read what I have written, and allowed me to go on looking in from outside.

On the other hand, I have had no influence on the anti-nuclear lobby, which sees me simply as an ally of the industry; and little if any on the provincial governments. At the federal level, I have found the Hon. Jake Epp a willing listener, as were several of his predecessors. And I appreciate being used as a consultant by the French and Swedish utilities. I have learned a great deal, but have little opportunity of putting my learning to good use -- apart from the credits I have just listed.

Canada simply cannot afford to do without the use of nuclear energy. My original field of expertise was climate, and especially climatic change. I can assure you that the greenhouse effect is no illusion, and that to reduce the use of carbonaceous fuels is an essential step to which all nations will have to come. I applaud the current move towards conservation and demand management. Without doubt it can do a great deal. But I do not believe, at age 73, that successor generations will agree to do without cheap, abundant, reliable electric power; and conservation will not achieve that for long. I see no source that can provide substantial accretions to supply, other than nuclear power. And I am almost sure -- no sensible person is ever certain -- that we can render the harnessing of that power cheaper and safer than it already is. To my knowledge, no person has died in this country as the result of the operation of power reactors, and I very much doubt whether anyone has sickened. Again, I cannot be sure; but I have looked as hard as I can.

The great threat is now, as it has been ever since the first artificial fission, that nuclear technology will be put to nefarious use. The breakdown of the Soviet Union has posed
entirely new and menacing threats; large arsenals of nuclear warheads awaiting disposal; small armies of nuclear technicians thrown out of their jobs, and eager to work for anyone who can pay; various irresponsible governments and trigger-happy leaders; and petty nationalism striving to turn back what I had hoped we had learned, that the unity of the human race is the only sane destination for political effort.

In the U.N.'s effort to contend with this threat, which I consider mortal, IAEA has played a considerable but insufficient role, and we can be happy that Canadian individuals have contributed to this effort. Our federal government, too, has acted responsibly in support. But much more needs to be done -- not least by many of the people present in this room.

All I can suggest in closing is that the Canadian industry soldier on. A decade or so more of smooth, accident-free operation by our reactors -- presumably those already built -- with capacity factors high enough to keep prices within reach -- will do more to disarm the critics than the largest public relations effort. I hope, in ten years time, that my successor at this podium will be able to confirm my prediction. The only proof of safety is visible freedom from harm; and the only proof of economic viability is a price that the consumer can afford, and that is lower than that of competing sources. These are the challenges to which this Association should dedicate itself.
SESSION 2

THE INTERNATIONAL CANDU PROGRAM

SESSION CHAIRMAN

Donald S. Lawson
AECL CANDU
ABSTRACT

Session - The International CANDU

KOREA'S TEAM CANDU

by

Chung Bo Hun and K.J. Petrunik
KEPCO        AECL CANDU

KEPCO with the support of AECL and other Korean and Canadian subcontractors has created a strong multi-company team to execute design and construction of the Wolsong 2 CANDU 6 power plant.

Key concepts of the project team are:

1. KEPCO is the project manager and AECL is the Engineering Contractor.

2. Significant participation by Korean companies in design work in Canada and Korea.

3. Significant manufacturing in both Canada and Korea.


Key concepts of the Wolsong 2 design are:

1. Evolutionary improvement of the Wolsong 1 plant which balances proven technology and necessary design improvements including current codes and standards.

2. Sharing of some structures with the Wolsong 1 plant.

This paper describes the successful establishment and operation of the complex project interfaces along with the current project status and plans.
KOREA'S TEAM CANDU

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Approximately one and a half years ago on December 28, 1990, KEPCO and AECL concluded contract negotiations with the South Korean government-owned utility, Korea Electric Power Company (KEPCO), whereby KEPCO would purchase a second CANDU 6 reactor.

KEPCO with the support of AECL and other Korean and Canadian subcontractors has created a strong multi-company team to execute design and construction of the Wolsong 2 CANDU 6 power plant.

Key concepts of the project team are:

1. KEPCO is the project manager and AECL is the major engineering and supply Contractor.
2. Significant participation by Korean companies in design work in Canada and Korea.
3. Significant manufacturing in both Canada and Korea.

Key concepts of the Wolsong 2 design are:

1. Evolutionary improvement of the Wolsong 1 plant which balances proven technology and necessary design improvements including current codes and standards.
2. Sharing of some structures with the Wolsong 1 plant.

This paper describes the successful establishment and operation of the complex project interfaces along with the current project status and plans.
1. LINKS BETWEEN KOREA AND CANADA

The Republic of Korea is quite densely populated, more than 40 million people, in an area of about 99000 km² (approximately twice the size of Nova Scotia).

Korea is among the world's fastest growing economies, and has forecast a 7% annual GNP growth in the 1990s. Korea has developed one of the world's most intense nuclear program (Korea's Long Term Plan for Power Development calls for 18 new nuclear plants to be inservice by 2006 - See Figure 1).

Canada and Korea have developed very close ties. Canada and Korea are each others 6th largest trading partners (1991 Canadian exports to Korea amounted to $1.86 billion, with two way trade amounting to nearly $4 billion. Canada ranks third as recipient of Korea foreign investment.

These ties have been brought even closer with the agreement to proceed with the Wolsong 2 reactor project and the establishment of shared project teams.

2. PROJECT TEAM

KEPCO holds the overall project management responsibility. KEPCO has entered into four major contracts for the implementation of this project, two with AECL - See Figure 2,3.

1. The first KEPCO contract with AECL covers the architect/engineering (A/E) function for the overall plant, procurement services in Canada (BOP) plus project management and owner support services.

2. The second contract with AECL covers the supply of the nuclear steam supply system (NSSS).

3. The third major KEPCO contract is with Korea Heavy Industries & Construction Co. Ltd. (KHIC) for the supply of the 700 MWe (gross) turbine-generator and the associated equipment. KHIC has subcontracted the design and manufacture of the turbine-generator to General Electric in the United States.

4. The fourth major contract is with the Hyundai Engineering and Construction Co., Ltd., covering plant construction.

KEPCO is a major purchaser of Canadian uranium and has developed in Korea its own refinery and fuel manufacturing facilities. KEPCO will therefore supply its own fuel.
Under the NSSS contract (#2 above), AECL will perform the design, supply and quality assurance functions for the major equipment in the nuclear steam supply system (e.g., the reactor, fueling machines and fuel handling equipment, heat transport system, moderator system, reactor control and safety systems, etc.). AECL also retains the same functions for some of the major equipment in the auxiliary systems, usually referred to as the BNSP (balance of nuclear steam plant).

AECL has also subcontracted some of the NSSS and BNSP detailed design work to the Korea Atomic Energy Research Institute (KAERI). KAERI has assigned staff to work at the AECL offices in Mississauga and Montreal and will perform the remainder of its work at its office in Taejon, Republic of Korea. Approximately half of the equipment and material required for the Wolsong 2 plant will be supplied through an AECL subcontract with KHIC. KHIC is based in Changwon, and has set up a procurement office in Mississauga.

Under the A/E contract (#1 above), AECL has subcontracted scope to CANATOM Inc., the Montreal-based nuclear engineering company, and NPM. A further subcontract has been set up with the Korea Power Engineering Company Inc. (KOPEC), to provide KOPEC participation in the total A/E scope of work.

Under its subcontract, CANATOM will handle the overall plant design and will provide the design and procurement-initiation function for the major equipment in the Balance-of-Plant (i.e., the conventional part of any thermal generating station) and the remainder of the BNSP, including the Reactor Building structure.

NPM will provide project management services, and KEPCO management training. NPM will also supply the owner support services (i.e., systems, procedures, and other tools) that KEPCO will need to manage the total project.

The two KEPCO contracts with AECL (#1 PLUS #2) have a total value of about $600 million, of which roughly one-third will go to Canadian manufacturers, one-third will be consumed by AECL, CANATOM and NPM, and one-third will go to AECL's Korean subcontractors. KEPCO and the Korean subcontractors currently have close to 100 of their staff working at the AECL, CANATOM and NPM offices in Montreal and Mississauga.

3. WOLSONG 2 DESIGN

The Wolsong 2 plant has 128 significant design improvements compared to Wolsong 1. These improvements represent changes due to evolution of the CANDU 6 (see Figure 4,5) design and results in:

* improved safety and reliability
• improved operations
• improved cost
• overall improvement to the plant.

The Wolsong 2 improvements can be separated into 5 categories:

a. Changes due to updated licensing requirements (December 1989)
b. Changes due to updated codes and standards (December 1989)
c. Changes due to sharing of systems with the Wolsong 1 unit
d. Design improvements
e. Changes due to improvements in technology.

There is a total of eighty-four (84) significant changes in the NSSS (Nuclear Steam Supply System) - See Figure 6.

3.1 NSSS Changes Due To Updated Licensing Requirements

Wolsong 2 licensing requirements are as of December 1989. There are twenty-one (21) such requirements. The changes represent the requirements for new plant construction in Canada.

For example Wolsong 2 provides improvements to the ECC control panel to reduce congestion to provide easier testing and monitoring by the operator.

3.2 Changes Due To Updated Codes And Standards

The codes and standards are updated to December 1989 requirements. There are 10 generic changes that apply across the NSSS design. The changes impact many aspects of the design.

For example application of current codes and standards for NSSS process systems leads to design of nuclear Class 1, 2 and 3 pipe hangers to meet updated requirements of the ASME code (subsection NF).

3.3 NSSS Changes Due To Sharing With Wolsong 1

Wolsong 1 made provision to share certain systems with a second unit. There are 14 such changes in the NSSS. Wolsong 1 made provision for two units capacity in some systems.
For example, the D$_2$O upgrader provided on Wolsong 1 was designed originally for two units. Operating experience indicates that there is sufficient reserve to upgrade D$_2$O from a second unit.

3.4 NSSS Design Improvements

Changes to improve operation of NSSS. There are 27 such changes. Many of these changes were KEPCO initiated and supported by AECL.

For example, by minor changes in layout, visual inspection of the delayed neutron sensing tubing can be improved.

3.5 NSSS Changes Due To Improvements In Technology

These changes result from improved products or manufacturing technologies. There are 12 such changes. Many of these changes are in the control, instrumentation, and computer area of the design.

For example, modern equipment such as CPU, disc drives, printer and printer tape drive provides an upgrade to the station computer system.

There are a total of forty-four (44) BOP (Balance of Plant) changes, which can be categorized in a similar way to those of the NSSS.

4. AECL SCOPE

AECL is the lead engineering and supply prime contractor. KEPCO and AECL have developed a strong multi-company team of Canadian and Korean subcontractors to execute the Wolsong 2 project.

4.1 AECL NSSS Scope

The participants are: AECL, KAERI, KHIC, NPM and suppliers

The scope includes:

- Replication Of The Wolsong 1 NSSS Systems And Components Design with approved changes:
- Preparation of input to Preliminary Safety Analysis Report (PSAR) and Final SAR (FSAR).
- Procurement of NSSS Equipment for the firm price scope Onshore and Offshore (e.g., in Korea and elsewhere).
- Preparation of Engineering Quotation Requests for the onshore Balance of the Nuclear Steam Plant Equipment.
Preparation of tender documents and supply of procurement services for the offshore balance of the Nuclear Steam Supply Equipment.

Training of KEPCO and KAERI personnel

Supply of Technical Assistance

4.2 AECL Architect Engineering Scope

The participants are: CANATOM, NPM, KOPEC.

The scope includes:

- Engineering and design services including the design of BOP, procurement, engineering and preparation and editing of PSAR and FSAR.

- Project management services including project management procedures, cost control and schedule, Q.A. Manual and Project Management Systems.

- Procurement services in Canada for BOP equipment.

- Provide KEPCO with Owner Support Services as required (Project/Construction Management).

5. PARTICIPATION BY KOREAN COMPANIES IN CANADA

As the principle of Korean participation in the project is embedded in the project, the Korean companies early in the project established offices and staffed their Canadian operation.

For example, the NSSS engineering subcontractor KAERI has established a 50 person engineering team to work in AECL offices as a joint AECL/KAERI design team. This integrated team work side-by-side to execute the broad range of engineering functions normally associated with CANDU design, including:

Reactor and Fuel Handling System Engineering

- Reactor Structural Design
- Major Components Analysis
- Fuel Handling Process Engineering
- Fuel Handling Mechanical Engineering
- Fuel Handling Control Engineering

Process and Equipment Engineering

- Process System and Piping Design of PHT and Auxiliary System
- Process System and Piping Design of Moderator System
- Process System and Piping Design of S/G Feedwater and Blowdown System
- Process Equipment Engineering for Fabricated Equipments, Machinery and Bulk Ordered Equipment

Control and Instrumentation
- Process Control Systems (Reactor, S/G, Auxiliaries)
- Plant and Reactor Control
- Safety System (SDS1, SDS2, ECCS)
- Station Control Computer Hardware and Software

Safety and Licensing
- Licensing
- Safety Analysis
- Probabilistic Safety Assessment
- Reactor Physics
- Reactor Shielding
- PSAR/FSAR

Interface Integration and Project Management
- Planning/Scheduling
- Project Control
- Document Control
- Reporting

In addition, as the Architect Engineering subcontractor KOPEC established a 50 person team in Canada to work side-by-side with CANATOM to perform the Conceptual design in areas of the Balance of Plant (BOP).

As well KHIC has established an office in Canada to perform quality surveillance and work on Canadian manufactured equipment.

KEPCO as Owner and Project Manager has established an office at AECL in Canada to manage the overall work being done in Canada.

6. SIGNIFICANT MANUFACTURING IN BOTH CANADA AND KOREA

Consistent with the Korean national goals, KEPCO has structured a localization plan that calls for substantial Korean supply activities.

About 40% of NSSS equipment is supplied by KHIC. The balance will be supplied by AECL. The turbine generator will be mainly fabricated at KHIC in Korea. The majority of the BOP equipment purchases will be supplied in Korea.

Thus the suppliers of major components involve both Canada and Korea as can be seen in Table 1.
TABLE 1

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<table>
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<tr>
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<th></th>
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<td>KHIC (with B&amp;W)</td>
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<td>Calandria</td>
<td>Canada</td>
</tr>
<tr>
<td>Fuel Machine</td>
<td>Canada</td>
</tr>
<tr>
<td>Reactor Feeders Header &amp; Frame Assembly</td>
<td>KHIC</td>
</tr>
<tr>
<td>Major Heat Exchangers</td>
<td>KHIC</td>
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<td>Turbine Generator</td>
<td>KHIC (partly GE)</td>
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<td>BOP Equipment</td>
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<td>PHT Pumps</td>
<td>Canada</td>
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</table>

7. PROJECT STATUS AND PLANS

In summary, the project is fully mobilized and on schedule.

Conditional Site approval has been given to KEPCO by the Ministry of Science and Technology (MOST) and Korean Institute on Nuclear Safety - The Korean Regulatory (KINS).

KEPCO submitted the Preliminary Safety Analysis Report (PSAR) and application for Construction Permit in 1991 September, on schedule. KEPCO is confident at this stage that approval for Construction Permit will be granted shortly by MOST and KINS.

Hyundai is well along with site preparation and excavation, and the first containment concrete is expected to be poured in the summer of 1992, with the target of commencing slip forming of the reactor building perimeter wall in 1992 November.

Design modification work at AECL and CANATOM is on schedule.

Purchase orders in major NSSS equipment have been placed, including the orders for the calandria, pressure tubes, fuelling machines, steam generators, the primary heat transport pumps and motors, and station control computers.

8. CONCLUSIONS

Korea's Team CANDU has developed an excellent working relationship, and design and procurement work is on schedule.
Both KEPCO and AECL look forward to building on that relationship, and extending it for future reactor projects consistent with Korea's long term energy plan. In this context, negotiations between KEPCO and AECL for Wolsong 3&4 are currently underway, and there is a plan to begin, soon, a feasibility study regarding a "large" CANDU plant design for Korea.
FIGURE 1

Long-term Plan for Power Development (preliminary, not authorized by government)

<table>
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<tr>
<th>Year</th>
<th>Month</th>
<th>Plant Name</th>
<th>Total Capacity</th>
<th>Peak Demand</th>
<th>Reserve Ratio (%)</th>
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FIGURE 2
WOLSONG 2 CONTRACTUAL PARTICIPANTS

KEPCO

OVERALL PROJECT MANAGER

ARCHITECT ENGINEERING
AECL

see next chart

NSSS Engineering and Supply
AECL

see next chart

T/G Supply
KHIC

Sub Contract
GE

Fuel Supply
To be Determined

Construction Contractor
HYUNDAI CO.

On-Shore Subcontractor
KHIC/Suppliers

BOP Equipment
KEPCO

Off-Shore Subcontractor
Canadian Supplier

Commissioning and Operations
KEPCO
FIGURE 3
BREAKDOWN OF AECL SCOPE FOR WOLSONG 2 PROJECT

KEPCO
OVERALL PROJECT MANAGER

Canadian Scope
• Technical Service
NPM

Canadian Scope
• BOP Design
• Procurement
CANATOM

Korean Scope
• Technical Service
KOPEC

Canadian Scope
• BOP Design
• Procurement
CANATOM

Korean Scope
• Technical Service
KOPEC

Canadian Scope
• NSSS Design
AECL

Korean Scope
• NSSS Design
KAERI

Canadian Scope
• NSSS Engineering and Supply
AECL

Korean Scope
• NSSS Equipment
KHIC

Selective Equipment
• NSSS Equipment
Suppliers

Contractual Linkage

Technical Management
Genealogy of CANDU Reactors

**Power Reactors**
- CANDU 1250 study
- Darlington 4 x 861 MW
- Bruce B 4 x 756 MW
- Bruce A 4 x 740 MW
- Cernavoda 5 x 600 MW
- Wolsong 1 629 MW → Wolsong 2
- Cordoba 600 MW
- Point Lepreau 633 MW
- Gentilly 2 636 MW
- Pickering A
- Gentilly-2 250 MW
- RAPP-2 203 MW
- RAPP-1 203 MW
- Pickering B 4 x 515 MW
- Douglas Point 206 MW
- KANUPP 125 MW
- NRX
- NRU
- WR-1
- TRR-P
- CIRUS
- ZEEP
- PTR
- ZED-2
- Slowpoke

**Research Reactors**
- Ongoing Research

Timeline:
- 1945
- 1950
- 1955
- 1960
- 1965
- 1970
- 1975
- 1980
- 1985
- 1990
- 1995
- 1998
Design of Wolsong 2
Based on Reference Design

Reference Designs

Original C-6 Family

Wolsong 1 Design

BOP

Specified Improvements/Changes Applied

Wolsong 2 Design

NSSS

As-built Data

Other CANDU 6 Plant Data

As-built Data

Other CANDU 6 Plant Data
Wolsong 2 Design Improvements/Changes Applied to Reference Designs

- Updated Licensing Requirements
- Updated Codes & Standards
- Sharing with Wolsong 1
- Design Improvements
- Improvements in Technology

Reference Design

Wolsong 2 Design

Evolutionary Design Changes

Future C-6 Project

Total of 128 Beneficial Improvements
CERNAVODA NPP – Its Place in Romania's Power System

A paper by

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Dr. K. J. Petrunik, Vice President, AECL Projects
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Presented at

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INTRODUCTION

The Cernavoda NPP is under construction in Romania, on a site located on the right bank of the Danube River, about 160 kilometres east from Bucharest.

Each Cernavoda CANDU unit, with a rated capacity of roughly 705 MW(e) will, in addition to being Romania's first nuclear power plants, be the largest generating stations in Romania, where the largest single installed capacity unit so far, has been a 330 megawatts (electrical) coal-fired station.

In 1991 the total installed capacity in the Romanian National Power System was 22,380 megawatts, distributed as follows:

- 8,680 megawatts - in coal-fired plants;
- 8,020 megawatts - in hydrocarbons plants and
- 5,680 megawatts - in hydroelectric plants.

However, the average generated power was only 6,490 megawatts (2,040 megawatts in coal fired and 2,820 megawatts in hydrocarbons plants). At the same time, Romania had to import about 900 megawatts, and was forced to limit consumption of electrical energy to some important industrial consumers.

This low load factor is a chronic problem for Romania's thermal power stations and stems mainly from two causes:

1. Station equipment is unreliable and coal supplied to them is poor quality.
2. In the past two years, shortages of gas, oil and coal-- both domestic and imported-- were a fact of daily life.

In the period following the December 1989 Revolution, as a result of socio-economic changes taking place in Romania, industrial electrical power consumption decreased. But Romania still had to import large quantities of electricity and fuel.

The above-mentioned situation demonstrates Romania's need for reliable power plants, whose dependence on imported fuel is minimal. Romania decided that the best answer to this need would be a CANDU nuclear power plant. The decision to build such a plant in Romania was made many years ago, and time has proved it was correct.

Today in Romania we think, almost unanimously, that the Cernavoda NPP is the only possible solution for our electrical energy shortage. However, the completion of all five units requires heavy efforts for our country, a major challenge, especially when one considers that, for the moment, internal demand for energy is actually decreasing and financial resources are very limited.
So, at present, Romania is focusing its attention on the completion of units 1 and 2 of the Cernavoda NPP.

SHORT HISTORY OF THE PROJECT

During the 1970s many studies were performed by Romanian specialists, or jointly with foreign partners, before deciding on building nuclear power plants and the selecting the reactor type. CANDU was chosen, taking into account its ability to use natural, non enriched, uranium, as well as its superior safety features, seismic qualification and excellent operational performance.

For the original Cernavoda NPP implementation plan, Romanian organizations signed contracts with AECL and the Consortium ANSALDO - GENERAL ELECTRIC (AI-GE). These contracts, signed in December 1978, provided engineering services (documentation delivery, technical assistance for operating personnel training) and procurement services for construction of the nuclear steam plant of the first unit at Cernavoda NPP. Later on, procurement contracts with AECL were extended for 2 units, and many separate contracts were signed with Canadian manufacturers to supply nuclear equipment for units 1 and 2.

In February 1981, Romanian organizations signed a contract with AI-GE providing both engineering services and equipment supply for the balance of plant, or BOP, for units 1 and 2.

Work at the Cernavoda site began in April 1979, with a scheduled date for first connection to the grid set for December 1985. The schedule proved to be unrealistic considering the conditions of the centrally planned economic system which existed in Romania until December 1989.

Construction was delayed by the previous regime's decision to limit, to the minimum amount possible, imports and hard currency costs. The former regime also decided to increase, excessively, the participation of Romanian industry in the supply of nuclear equipment and materials, starting even with unit 1. A cut-off of the loan received from the western banks in 1982-1983, was another reason for the delay of work at the site.

In 1989, under political pressure to accelerate work, the amount of pipe welding performed monthly on site was increased — unfortunately, without providing an adequate means of quality control. Subsequently, when the rate of defective welding was found unacceptable, work on site was stopped for inspections and corrective action.

Then came the revolution in December 1989, and the former regime was overthrown. During 1990 all efforts were dedicated to
repairing defective welding, and to improving the overall level of quality control.

In 1991 the civil works were practically completed (about 90%) on unit 1, and the status of completion of the equipment installation was approximately 55%.

From 1979 until 1991, the project was managed by Romanian organizations. They employed the usual methods of running investment projects— including involvement of central administration— which chose the contractors (design institutes, construction companies, equipment suppliers, etc.) and controlled the budget.

However, having the support of Canadian-Italian technical assistance, and observing the requirements of the Romanian regulatory body (inspired by Canadian practice), we succeeded in implementing a Quality Assurance system in the activities of all the organizations involved in the Cernavoda project.

**IAEA Pre-OSART* MISSION (Operational Safety And Review Team)**

After the revolution, the new Romanian Government reconfirmed the country's commitment to complete the nuclear power project.

Considering the concerns expressed by media and the public, the Government invited the IAEA to perform a Pre-OSART (or Operational Safety And Review Team) study at the Cernavoda construction site. The purpose was to review construction activities and to have the IAEA make proposals to enhance work quality and safety practices.

The main conclusions of the IAEA mission were highlighted in the official report submitted to the Government of Romania.

The report underlined the advanced safety features of the CANDU design. However, the team reported that the Romanian project had suffered from the disadvantageous practices of the previous regime, with its consequent stifling of personal initiative, and from the imposition of an unrealistic schedule. The result of these practices was that staff became demotivated.

The most common shortcoming identified by the pre-OSART study was a failure to follow procedures. The results were visible in the poor condition of the site due, for example, to ineffective industrial safety and cleanliness controls, work left uncompleted, and sub-standard storage areas and prefabrication facilities.

Despite these problems, major plant items, such as the calandria and pressure tubes, steam generators, pressurizer, main turbogenerator and nuclear island piping had been installed.
correctly and were being maintained adequately. However, in many cases there was a high cost to correct sub-standard work.

The pre-OSART mission at NPP Cernavoda made 166 recommendations and suggestions. Some of these dealt with overall problems such as project management, quality assurance and social problems. Others dealt with the details of construction work (civil, mechanical and electrical, C & I installation). A number of suggestions were directed towards improving the plant’s prospective plan in the field of radiation protection and emergency preparedness.

Most importantly, the Mission also recommended that the owner be given the freedom and authority to manage the project and to control the situation.

Since this is the first nuclear power project in Romania, the experts recommended that assistance in managing the project should be sought from an organization with long experience in construction. As a consequence, RENEL entered into an agreement with a consortium made up of AECL and ANSALDO.

The first task of the new AECL and Ansaldo Consortium, or AAC, was to perform an inspection of the engineering and construction status of Units 1 and 2 and to manage the repair of all identified deficiencies. All the technical and economic conditions set out in previous contract specifications are rigorously being observed and fulfilled.

It was agreed that the first priority is to be given to work on Unit 1, with a target of a 1994 start-up. For Unit 2, RENEL and AAC will perform the required activities with the intent to put this unit into operation not later than 1996.

According to the contract, the consortium is to involve Romanian staff in the performance of the work for the purpose of training and developing staff to perform future project management functions.

Scope of Project Management

Project Management Work
The AAC Consortium is managing the completion of construction, commissioning and initial operation of Unit 1, and the repair of Unit 2. Its activities include the provision of quality assurance assistance to nuclear components manufacturers.

To accomplish this, AAC established at Cernavoda site, a project-dedicated, integrated Project Management Team (or PMT). The team incorporates a group in Bucharest for Quality Assurance assistance for component fabrication suppliers. The PMT is led by a
project director. The actual number of PMT members is approximately 460 so far, including about 310 Romanians.

AAC is installing and implementing the same kind of project management systems and infrastructure that they and their subcontractors are using in their international business.

On the customer side, RENEL, is to provide in a timely manner, all resources, work, services tools, equipment, materials and supplies, subcontractors and customer personnel— including operations staff— as deemed necessary by AAC.

**Assistance Services**
AAC has attached management and specialized personnel to subcontractors and other organizations in Romania in order to provide managerial, technical and construction assistance services.

**Engineering Services Work**
AAC performs, or ensures performance of, the engineering services required by the project. It also co-ordinates the design work and responsibilities for the Nuclear Steam Plant, Balance Of Plant and support services, for the purpose of ensuring the functional performance of the Unit.

Engineering services include mainly:
- engineering status verification,
- review of work packages,
- review of design for additional systems,
- resolution of licensing and safety issues,
- resolution of field construction and commissioning problems,
- review and approval of as-built drawings,
- identification of exceptions upon turn-over etcetera.

Such services may be performed at AAC's option, by a Romanian design organization, or by AECL, or ANSALDO.

**Procurement Services**
AAC initiates and manages procurement of goods and services from within or outside Romania, in order to fulfil the requirements of the project. AAC is committed to manage procurement of equipment from outside Romania in order to maximize Romanian content of all purchases. Naturally, quality, cost and schedule requirements remain foremost in our considerations in this regard.

**Operations Staffing and Training**
AAC will guide the selection and provide training of Romanian operational staff. Formal classroom and on-the-job training will be conducted in Romania and in Canada (at the Point Lepreau CANDU 6 reactor and full scope simulator) for managers, shift supervisors, first and second operators, specialists and maintenance staff. A total of about 90 Romanian staff will be trained in
Canada for periods ranging from four (4) to twenty-four (24) months.

Commissioning and Operation Services

The AAC operations personnel will lead and supervise pre-commissioning, commissioning and initial operation activities. For this purpose, RENEL will provide the full complement of station operating staff. By the end of the initial operation period, AAC operation personnel will transfer leadership and supervision on a person-by-person basis to the Romanian operating staff, as they become trained and capable.

In performing its activities in this area, AAC will:
- issue the required documentation (commissioning procedures and schedules, operating manuals, maintenance procedures, spare parts and consumables lists, etc.) and
- lead the Romanian staff in preparing the necessary documents for the Romanian Licensing Authority, as well as in the preparation of operating documents for radiation protection, emergency procedures, abnormal incidents manuals and training manuals.

With support from Romanian staff, AAC will:
- perform the commissioning, initial operation and maintenance including in-service inspection, making all required technical decisions in all technical matters related to operation,
- accept the turn-over of each system from construction to commissioning, evaluate tests and performance results, and
- accept the systems to be in-service, rectify equipment and system deficiencies and make any field modifications required during commissioning.

A main preoccupation will be the training of the Romanian operating staff, making them gradually responsible for technical decisions.

Others

Also, AAC will prepare the Project Quality Assurance Manual and related procedures (which are to be submitted to the Romanian Licensing Authority) and provide technical assistance and support to RENEL for preserving the equipment installed in Units 3, 4 and 5, until construction attention is turned to them.

THE PROJECT MANAGEMENT TEAM AND ITS ACTIVITIES

The AAC Project Management Team (or PMT) has been given full authority to manage the project on behalf of, and in RENEL's interest. At the same time, RENEL committed to provide all
resources required to complete the project. These include domestic and foreign funds, accommodation and facilities for AAC personnel, material supplies, human resources and documentation previously produced for the Project.

As station owner, RENEL remains the ultimate authority with respect to all aspects of construction, commissioning and operation. RENEL:

- reviews the annual budget and updated Project schedule presented by AAC every six months;
- reviews the work orders issued by AAC for supply of goods and services from outside Romania;
- accepts the payments to subcontractors based on AAC approval of invoices;
- receives periodic reports from AAC on the Project status; and
- performs audits and inspections on the Project Management Team activities.

AAC has the responsibility and authority to determine expenditure allocations within the established annual budget. The total value of funds required for project completion was jointly estimated and the annual budget expenditures will observe this limit.

In managing the subcontractors, the PMT acts as RENEL's agent in all matters relating to the negotiation, performance, administration and termination of the contracts. The provisions also cover the renegotiation of contracts in effect before the renewed RENEL - AAC relationship was put into place. This refers mainly to the contractors for site construction work, which are involved in the project from 1979 to 1986.

AAC may replace those Romanian contractors found unacceptable to them with other Romanian firms. In the event that acceptable Romanian sources are not available, AAC may replace them with foreign contractors (following consultation with RENEL).

AAC has the right to stop any project work and require remedial measures, or to reject supplies and work which do not meet standards. Also, AAC may devise and implement an incentive program to promote quality, safety and productivity among Romanian personnel.

The PMT is organized as shown in Figure 1.

Personnel assigned to the PMT—Canadian, Italian and Romanian—were selected by AAC. The commitment was made to include Romanian staff as members of PMT, to the maximum extent practicable, consistent with their skills and capabilities.
The Romanians, accepted for secondment to the PMT, belong mainly to the staff of the Cernavoda station and were previously engaged in the construction of Units 1 to 5 as representatives of the owner. The number of AECL - ANSALDO employees in the PMT, during the peak period, is estimated to be about 400.

PMT Groups

The Project Director, appointed by AAC, leads the PMT, manages budget allocation and implements overall objectives of the contract. With the help of PMT managers and their staff, he implements the project plans, including the supplies and services to be provided by other participants to the project.

The PMT's functions include:
- liaison with the customer, RENEL;
- quality assurance and surveillance;
- engineering management;
- planning and scheduling and resource determination;
- budget allocation and evaluation;
- progress evaluation;
- work measurement and reporting;
- contract administration;
- construction and commissioning/operation management;
- accounting personnel services;
- administration;
- office services;
- industrial safety and audits.

The senior project managers are responsible for developing, assigning and monitoring work packages, related schedules and manpower requirements for that portion of the work within their responsibility. They also ensure that the quality of supply and services conforms to established procedures and standards.

Engineering / Quality Surveillance Group - is responsible for overall direction, co-ordination, administration of all engineering services and execution of quality surveillance activities for Nuclear Steam Plant, Balance of Plant and Support Services.

Construction Group - is responsible for overall direction, co-ordination and administration of all construction activities for the Nuclear Steam Plant, Balance of Plant and Support Services. The Project Management Team, or PMT, manages construction work as a number of subcontract packages, aiming to maximize productivity and progress. AAC provides assistance services staff to be attached to the subcontractors to co-ordinate and liaise with the PMT and to provide expertise. They will promote enhanced productivity and work quality.
The project is construction-driven. Engineering supports the requirements of construction and all other project services will be oriented to meet the need of construction.

The Commissioning and Operations Groups - are responsible for overall direction, co-ordination and administration of all phases of plant commissioning and operation. It will total about 100 persons. The Operations Group is led by the AAC Station Manager.

In this group, a core staff of commissioning area superintendents will lead and manage an integrated team made up of selected personnel from the PMT, major equipment suppliers, construction subcontractors and Romanian station operating and maintenance staff.

The Services Group - oversees the following major areas: System Turnover, Material Control, Document Control, Contracts Administration, Finance and Administration and Industrial Safety. Among these, the Material Management Department manages all project materials, including procurement, warehousing and preservation of all equipment at site. It identifies shortages of materials from document lists and initiates procurement activities from either Romanian or foreign supply.

As most of the material and equipment has already been supplied, the status of its turn-over to the subcontractors is being checked and verified by PMT.

The Planning and Scheduling Group - establishes, monitors and controls the schedule aspect of the project. It will propose solutions in the event of any situation that could prevent meeting the scheduled objectives. The group uses a computerized level 3 system of schedules (Master Project, Co-ordination and Control, production schedules). The subsequent levels of schedules (4 and 5) will be prepared by subcontractors.

The Quality Assurance Group - establishes comprehensive programs to monitor compliance by project management, design, supply, manufacturing, construction and commissioning activities for the project in accordance with specified procedures, standards, safety and other requirements established for the project.

The QA group performs regular reviews and audits on each project participant to ensure that quality programs are being effectively implemented and that they comply with the project quality program standards.

Industrial Safety - has overall responsibility for assuring that working and hygienic conditions, physical protection and fire protection on the site are maintained in accordance with Romanian laws and regulations, and good safety and security practices.
Project Reporting
The PMT issues monthly reports to RENEL on the status and progress of all project activities required by contract. Progress is reported against the established plan with an emphasis on project areas that do not conform.

At the second level, each department submits to the project director, a monthly progress report including:
• performance trends,
• key events and highlights,
• problem areas and corrective actions summary schedule,
• cost status,
• procurement status and
• quality assurance status.

Any report relevant to the status and progress of the project will be made available to RENEL.

RENEL has the right to request from time to time, reports on areas of specific concern.

A monthly QA Conformance Report is submitted to RENEL, certifying quality assurance verification and approval of all works performed during the previous month.

QUALIFICATION OF THE NUCLEAR FUEL MANUFACTURING FACILITY

RENEL has a nuclear fuel manufacturing facility at the Nuclear Research Institute - Pitesti. This facility developed its own technology and produced a number of nuclear fuel bundles for CANDU reactors.

Following discussions and visits to Pitesti by AECL and ZIRCATEC I. P. representatives, it was agreed that the facility will be rehabilitated in co-operation with Canadian partners. It was also agreed that, subsequently, AECL will qualify the facility in Pitesti for production of CANDU fuel, and will certify the fuel manufactured there for use in the Cernavoda NPP reactors.

FINANCING

With AAC support, RENEL obtained a foreign currency loan required for the project. These loans represent $419 million dollars (US) and were received from the Export Development Corporation in Canada and Medio Credito Centrale of Italy. The loan convention has the guarantee of Romanian Government and was approved by our Parliament.

The down payment is to be paid at the beginning of June 1992, and the AAC - RENEL contract will become effective at that time. It is worth mentioning that activities on site and the special mobilization work have been performed adhering to principles of
both the contract and the Memorandum of Understanding, since July, 1991.

The necessary funds in Romanian lei will be provided by RENEL from its own resources and partially, by the Romanian Government.

REORGANIZATION OF RENEL'S NUCLEAR POWER GROUP AND CERNAVODA NPP

Following the advice of Canadian specialists, RENEL reorganized its Nuclear Power Group in Bucharest and its subsidiary, NPP Cernavoda. The purpose was to get maximum benefit from the Canadian utilities' experience and to set up an appropriate organizational interface with AAC during the project lifetime.

The overall organization chart for RENEL is shown in Figure 2. The organizational charts of RENEL's Nuclear Power Group and of Cernavoda NPP are presented in Figures 3, 4 and 5.

RENEL's Nuclear Power Group will:
- control the construction of Cernavoda NPP,
- represent the owner in its relationship with the regulatory authorities and
- develop the utility's policies in the area of NPP operation, maintenance, personnel training and so on.

The NPP Cernavoda Director is RENEL's fully-authorized representative on site. His purpose is to interface with AAC for implementation of the contract. The Cernavoda NPP organization is intended to create the appropriate conditions for station personnel to be involved in commissioning and operation and maintenance activities in accordance with the highest standards.

The work in the new conditions set up by the RENEL - AAC contract is still in its early stages. The good co-operation among Romanian, Canadian and Italian specialists continues to improve. This, plus the worldwide NPP construction experience of our partners and the support given by the Romanian Government, makes us confident in the timely and successful completion of the Cernavoda Project.
FIGURE 1  AAC Project Directorate
Technical Strategy and Services Division

- Technical Department
- Strategy Department
- Management, Personnel and Labour Relations Department
- Support Services Department

FIGURE 4
Investment and Preparedness for Operation Division

- Engineering Planning Contracts Department
- Estimating Finances Cost Control
- Procurement Department
- Construction Works Department
- Investment for Related and Collateral Objectives Department
- Commissioning Preparedness for Operation and Maintenance Department

FIGURE 5
PRESENTATION FOR CNA

CERNAVODA PROJECT STATUS

AUTHORS

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Mr. Roland Boucher, Project Director, AECL/ANSALDO/Consortium.

ABSTRACT

The Cernavoda Nuclear Power Project comprises 5 CANDU Nuclear Power Units with a Net Output of 633 MWe each, located in the same geographical area as Cernavoda Town, Romania.

The 5 Units present different degrees of progress, Unit 1 being the most advanced with nearly 60% overall construction completion. In this Unit, the civil works are 91% finished, the mechanical close to 63% and the electrical and C&I around 15%.

The entire Cernavoda Project was run in the past under RENEL responsibility, with AECL and ANSALDO acting as Technical Assistants for the NSP and the BOP parts respectively. In August 1991, the responsibility to complete and to bring into operation the Unit 1 was transferred from RENEL to a Consortium formed by AECL and ANSALDO.

Since September 1991, a significant Project re-arrangement was initiated, with substantial changes in:

♦ Project organization;
♦ Design responsibilities;
♦ Construction organization and supervision;
♦ Field verification and surveillance;
♦ Local and foreign procurement;
♦ Material control;
♦ Contracts for engineering and construction;
♦ Planning, scheduling and progress monitoring;
♦ Budgeting, cost control and financing;
♦ Romanian personnel training and development;
♦ Funding.

RENEL and the Consortium, in agreement with the Romanian Government, agreed to set the highest priority for the Cernavoda Project in Unit 1, with the main objective to get this Unit critical before the end of 1994.

Also, the Government Social Program required to improve the living conditions and infrastructure aspects of Cernavoda
and its vicinity merited particular consideration by the Romanian, Canadian, and Italian Authorities associated with the Project.

Work in the other Units was re-focused to clear non-conformances resulting from civil jobs in Unit 2 and to preserve the structures, material and equipment for Units 3/4/5.
The criticality dates for these Units were set starting from December 96 with one year difference between them.

The financial aspects for the work required in Unit 1 was solved by means of a Canadian loan (300 Million CD$), an Italian loan (175 Billion Lire) and a Romanian contribution (95 Billion Lei).

Presently, the Project Management Team established by the Consortium is composed of 170 Expatriates (Canadian and Italians) and 310 Romanians and this organization will still grow substantially in the coming months.
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1. THE PROJECT

The Cernavoda Nuclear Power Project is composed of five (5) Candu Nuclear Power Units with a Net Output of 633 MWe each, located in the same geographical area, close to Cernavoda Town in Romania.

Each Unit is based on the standard Candu 600 design, which is similar to the Nuclear Power Plants Gentilly II and Point Lepreau in Canada, Wolsung II in South Korea and Embalse in Argentina.

Since each Unit is essentially a "stand alone" CANDU 600 the Units can be operated in an autonomous way.

The Cernavoda Nuclear Project is a key element in the Romanian indigenous nuclear development and the selection of the Candu design represents a major contribution to this development due to:

- technological feasibility for manufacturing parts and components;
- use of natural uranium allowing fuel manufacturing in Romania;
- the support of AECL and ANSALDO for technical assistance;
- the experiences of other CANDU 600 plants built in countries with different degrees of nuclear development;
- the experiences gathered in operating CANDU Plants through the CANDU Owners Group.

The Romanian nuclear development program is complemented with a nuclear fuel manufacturing plant, a heavy water production plant and major organizations for engineering, manufacturing and erection for systems and components.

The technological transfer agreement between RENEL and AECL supported the Romanian participation in the Project, proposing an increasing degree of involvement from the first Unit to the last one.

2. PROJECT ORGANIZATION

The Station is the property of the Romanian Government and the Regia Autonoma Nationala de Electricitate (RENEI) is the state organization responsible for its construction and operation.

The Project was run under the direction of several Ministries from its initial stages, back in 1979 until 1990 when RENEL was created and from August 1991 by the AECL/ANSALDO Consortium.
The main technical support inside the Country for the Project were:

- different institutes reporting to RENEL for design and research, (ISPE, ISPH);
- manufacturing companies,
  - IMGB, Automatica, Vulcan, Resita, etc;
- construction companies, most of them created to meet project requirements,
  - Nuclearmontaj, CNE, TMUCB, AMEA, SIEA, NIMB, etc.

All these companies were state owned as a consequence of the political orientation taken by the Romanian Government more than 40 years ago.

Atomic Energy of Canada Limited, a Canadian Crown Corporation, acted as technical assistant for the Nuclear Steam Plant of the Project.

In addition to that, technological transfer agreements were signed for the design and manufacturing of key nuclear systems and components.

ANSALDO, a Society from the national IRI (Istituto per la Ricostruzione Industriale) Group in Italy, acted as a technical assistant for the conventional systems in the turbine generator building.

General Electric from the United States acted as a technical assistant for the turbine generator design, manufacturing and installation. A technological transfer agreement was signed with a major Romanian manufacturer (IMGB) for producing locally approximately 35% of the turbine generator components.

At the end of 1990, the discussions for a significant Project restructuring started and RENEL signed a contract with a Consortium formed by AECL and ANSALDO. The main scope of this contract is the provision of all resources, services, tools, equipment, materials and supplies required for the completion of Unit 1. The management and control of all work associated with Unit 1 including operating the Unit for a period of 18 months and the verification and rectification of civil work already completed in Unit 2.

The Contract entails extensive project management functions, engineering management and services, construction management and services, construction and engineering status verification and commissioning, operations and training management and services.

The AECL/ANSALDO Consortium (AAC) officially commenced its activities at the Cernavoda Site in August 1991 and as per the signed Contract, RENEL delegated to AAC all Project Management functions.
Since that time, there have been substantial changes in the following project areas:
- Project organization,
- Design responsibilities,
- Construction organization and supervision,
- Field verification and surveillance,
- Local and foreign procurement,
- Material control,
- Contracts for engineering and construction,
- Planning, scheduling and progress monitoring,
- Romanian personnel training and development.

The organization set up by AAC to perform the Project Management tasks is composed of:
- Project Director
- Deputy Project Director

- 5 Line Managers:  
  - Engineering/Quality Surveillance
  - Construction
  - Services
  - Commissioning
  - Station Operation

- 4 Staff Managers:  
  - Planning and Scheduling
  - Quality Assurance
  - Industrial Safety
  - Training

The AAC staff is composed of Expatriate personnel from Canada (AECL) and Italy (ANSALDO) which is drawn from a wide background of international project management and nuclear related experience.

AECL is staffing the Canadian part of the Consortium with extensive expertise from its Home Offices and other Utilities operating or involved in CANDU Projects (Hydro Quebec, Ontario Hydro, New Brunswick Electric Power Commission). In that way the experience from other CANDU Plants (Gentilly-II, Point Lepreau, Wolsung, Embalse, Pickering, Bruce, Darlington) is made available to the Cernavoda Project.

AN:ALDO is staffing the Italian part of the Consortium with personnel who worked in the past in the nuclear field in Italy or elsewhere (Caorso, Montalto di Castro, Creys Malville) and in many conventional power plants built in Italy and all over the world.

Presently the Project Management Team established by the Consortium is composed by 170 Expatriates (120 Canadians and 50 Italians). A peak of 350 Expatriates personnel is expected.
The AAC organization is complemented with Romanian staff who cover the following positions:

- "Deputy" or "Assistant to", for supervisory functions,
- Operative technical positions, mainly filled by engineers,
- Administrative, secretarial, and auxiliary positions.

It is intended that the Senior Romanian personnel in supervisory functions and the technical personnel attached to the Project follow intensive on-the-job-training through exposure to project activities developed by the Canadian and Italian counterpart of the organization.

The Romanian staff attached to AAC to form the Project Management Team are 310 persons and a peak of 350 people is expected, excluding the Operations phase.

3. SCHEDULE

The RENEL-AAC Contract includes a Project Master Schedule (Level 1) showing about 100 activities. These activities cover system installation, check out and turn-over to commissioning, commissioning of Unit 1 and operating the plant for the first 18 months of operation.

Despite the fact that the Contract is not yet effective, work has been planned and conducted in accordance with the original schedule developed in the contractual negotiations.

The target established was to have the Unit 1 synchronized to the grid in December 1994 and thus the highest priority for the Cernavoda Project is to accomplish this objective. For that reason, practically all the efforts and budget for the Project are assigned to Unit 1, performing just some remedial activities in Unit 2 and preservation activities for the other Units.

The last update of the Project Master Schedule showed the following status:

**Project Current Schedule Dates for Unit 1**

- Completion of PHTS* and auxiliaries piping 92.Nov.01
- Completion of Phase 3 bulk cabling 93.May.16
- Check out PHTS* and t/o to commissioning 93.Oct.24
- Heavy Water Loading (Mod. Syst.) 94.Aug.22
- Start Fuel Loading 94.Sep.19
- Criticality 94.Nov.07
- Synchronization to the grid 94.Dec.19
- Unit 1 in service (full-power) 95.Mar.27

* PHTS: Primary Heat Transport System
The current critical areas are:

**Resolution of Material/Tooling/equipment Shortages**

Resolution of material tooling and equipment shortages is on-going with the issuance of Work Orders for procurement in Canada, Italy and Romania. In addition, the procurement process of the different Contractors is being reviewed and a verification of the reliability in quality and delivery time has started.

**Installation of Bulk Cabling**

Bulk installation of cable remains a priority issue, with the potential to affect the turnover of systems and the overall Project schedule. The major areas of activity involve:

- planning, detailed production schedules, quantities to be installed, monthly and cumulative production curves;
- engineering, documentation delivery, verification at Site, release for construction, interferences resolution;
- materials, review of Work Order status and identification and follow-up of Contractor's suppliers;
- tooling, review of Site needs and Work Orders status;
- manpower, review of the Electrical Contractors personnel qualification and quantity;
- areas/space, cable coils storage areas, handling paths, areas released to work;

**Install and Check-Out Class IV Supply (110 kV System)**

The requirement to supply power for the testing of the Main Circulating Cooling Water Pump makes the Class IV Supply critical. The resolution of engineering problems is on going with a task-force formed by Engineering and Construction.

Significant material shortages and equipment deficiencies have been identified and resolved. The preservation for the 110 kV transformers is in progress.

**Main Computers Installation**

The tasks required to install the Main Computers Installation have been identified and incorporated into a detailed working schedule, which is being updated on a weekly basis.

**Training of Romanian Staff in Canada**

This activity started in 92 January and it will continue until the end of 1993.
The first group of 19 Shift Supervisors and Control Room Operators is in Canada since 92.Feb.01 and the second group of 28 Technical and Maintenance staff left Romania on 92.May.04.

**Install Bulk Instrumentation Tubing**

An intensive effort was mounted to improve the tube trays and tubing installation with good results, but the activity is impaired by lack of some materials and by mechanical construction constraints as well as a shortage of manpower. A special welding and testing shop was organized to increase the number of tube welding machines for production.

**Engineering Completion and Verification**

The engineering completion and verification is one of the critical areas of the Cernavoda Project. (See Chapters 4/5).

4. **ENGINEERING COMPLETION**

The detailed engineering for the Project is still not completed. In addition some areas need improvements and corrections due to past management methodology.

Too many discrepancies exist between the different design documents because they were realized independently by different design organizations and the manufacturers.

A thorough interferences analysis was only partially performed, and for this reason the construction activities are continuously held-up by interferences among piping, ventilation ducts, cable trays and conduits. As the civil works did not have an acceptable quality at all times, many embedded parts are out of tolerance, requiring re-routing of piping and cable trays and leading to further interferences.

To date, more than 10,000 site dispositions have been issued for the entire Unit 1 and their analysis and review represent a big work load from the engineering and quality surveillance points of view.

The Process and Instrumentation diagrams have shown some mismatches with the elementary drawings and the interconnecting diagrams thus requiring a comprehensive verification program.

The inventory of technical documents and drawings in the Client's hands at Site was very limited due to the fact that many documents were held by the design organizations in Bucharest and that the Site documents were distributed to Construction Contractors or ended up in personal files.
Completing the Site files is part of the Document Control program and requests have been given to the different organizations involved to send back documents to the central files. A verification process is on going to assure that the applicable documents are being used for construction activities.

A scanning and plotting system will be incorporated into this program shortly as a solution to re-create the original documents and to allow revisions and modifications in the short time needed to complete the Project.

The engineering services contract with the design organization (ISPE) was signed in February 1992. With the signature of this contract, AAC has implemented a new method to process the engineering work for the Cernavoda Project: the design activities are now requested by means of Engineering Work Packages (EWPs) issued by AAC Engineering/Quality Surveillance Division.

Finally, it was agreed that the direct hours of the EWPs will follow the Canadian and Italian estimates, but will be adjusted by multiplying factors to consider the lower local productivity and the indirect tasks. Each EWP has to be discussed thoroughly before a final agreement is reached.

35 out of 55 Engineering-ISPE Romanian Positions at Site are already filled.

Complete coverage of ISPE engineering activities in Bucharest will be done by the presence of Expatriate staff (Engineering Deputy Manager plus two Engineers), acting as AAC representatives. These representatives will manage engineering activities, will assume liaison with the Site and will provide assistance to the ISPE organization.

The Design Authority for the Project has been re-defined and established as follow:

- AAC is the Design Authority for the Nuclear Steam Plant and the Balance of Plant;
- ISPE is the Design Authority for the Support Systems. For this purpose, ISPE is represented at Site by the Design Authorities Representatives (DAR), composed of three persons integrated into the Engineering/Quality Surveillance Division.

In order to prevent further delay in the Project realization, considerable effort is required in the following areas:
- Delivery of the engineering information;
- Verification of the engineering;
- Verification of all construction work done in the past.
Periodic meetings have been implemented with the State Inspection Authority for Boilers and Lifting Devices (ISCIR) to define clearly the interfaces and responsibilities and to resolve pending matters. Good results were obtained from these meetings and a spirit of cooperation has been achieved.

5. PROJECT STATUS VERIFICATION

One of the most important elements of the new Contract is the verification of the engineering and construction status. AAC has to manage all design activities and to coordinate the resolution of design issues, including interface issues, arising out of the execution of the Project to date.

Main aspects of this task are:

a) Check compliance with AECL/ANSALDO equipment specifications and quality requirements of Romanian supplied equipment and materials;

b) Check in-store supply, to verify compliance with storage requirements and equipment functionality subsequent to storage;

c) Check in-field supply, to verify equipment functional capability after in-field erection and storage;

d) Check that all designs to be supplied by AECL or ANSALDO pursuant to the previous contracts are complete;

e) Check civil and steel structures for geometry, connections and embedded plates, producing as-built reference drawings;

f) Check systems and components previously erected to assure proper erection has been done, producing as-built reference drawings;

g) Perform required Non Destructive Examinations for the systems that Engineering require to be qualified;

h) Initiate required remedial, repair or replacement work;

i) Check that the design, specification and reliability of equipment conforms to overall Station design requirements.

The major verifications programs in place since the Consortium took over the Project are:

• Anchor verification program in the Reactor Building (2636 anchors tested) and in the Service Building (1173 anchors tested) of Unit 1, with rejection rates of 14.6% and 59.5% respectively.
Large bore weld repairs in the Turbine Building, with more than 1000 welds repaired, inspected and accepted.

Cable trays reinforcement, with more than 10000m of cable trays modified.

Closing the piping system route cards through the checking of inspection documents against the as-built condition and verifying modification implementation on 50 process systems already installed.

Detailed field verification of 4 process systems is complete with other 3 being complete.

A major civil repair program was conducted in the Reactor Building containment structure filling cracks by means of concrete injection and checking for the presence of possible concrete voids using ultrasonic methods.

A major civil repair program is ongoing to close more than 150 Non Conformances in the Reactor and Services Buildings of Unit 2.

Refurbishing programs:
  - 6, 1C, 24 kV bus ducts;
  - Motor Control Centres;
  - Lighting in the Pumphouse;
  - Switches and breakers in the 110 kV Station;
  - Infiltrations repairs in the Pumphouse

The immediate programs to be initiated are:

- Site disposition verification and closure, with more than 10000 Site dispositions to be reviewed, of which 3000 were previously declared closed by the Contractors.

- Non conformance review and analysis, with more than 3000 reports to be verified.

- Ventilation equipment and ducting to be verified and upgraded.

- Spent fuel bay leakage repair.

6. ROMANIAN COMPONENTS HOMOLOGATION

Many components for the Cernavoda Project were designed and manufactured in Romania by suppliers who did not have previous nuclear experience. The local Authorities requested that the components be homologated (ie. certified) before their use in the nuclear plant and a series of stringent requirements were established for testing and verification purposes.
Small process equipment like pumps, heat exchangers or valves could be homologated directly in the supplier premises or in national laboratories.

Some components were not totally qualified before being shipped to Site and that situation requires careful analysis before decisions are taken on how to proceed. This is the case for 200 electrical motors which were not tested at the factory to verify their behaviour in the case of Loss of Coolant Accident.

The most important issues are the Main Circulating Water Cooling Pumps and the Stand-by Diesel Generators, Class III, which were totally manufactured in Romania without previous experience of the manufacturers in components of such characteristics and size.

For the Main Circulating Pump a prototype homologation test has to be performed on Site, because the supplier did not have an adequate test loop of large dimensions. In that regard, two tests are foreseen. The performance test will be done in a closed circuit delivering the flow through another Main Pump intake. This requires the installation of a temporary circuit of large dimensions which will allow the measurement of the characteristic curves and other important performance parameters.

The endurance test will require the Pump to be run for more than 500 Hours and a decision has to be taken if the Main Condenser and the cooling circuit will be used during the test.

A special task-force was created for this activity with the Engineering, Construction and Commissioning staff present at Site with the cooperation of RENEL and the participation of the manufacturers.

One of the Diesel Generators was tested in the supplier's shop, but the end results were poor with serious damage of the internals of the engine. Analysis and modifications to the test procedure for this unit are being done for pursuing the homologation. The other Diesel unit is installed at Site and a major retrofitting is expected.

7. CONTRACTUAL ASPECTS

Managing the Cernavoda Project involves the resolution of serious contractual matters. Nine Construction Contractors were working at Site when AAC took over the Project.

Previously, the contractual obligations between the Owner and Construction Contractors were not strictly observed, as a consequence of the complex interactions of different organizations in the centrally planned nationalized economy. The
payments to Contractors were not always directly connected with the volume and quality of performed work.

The large overheads and the disparate organizations led to an indirect/direct manpower ratio of more than 100% in the worst organized Contractors with an average of 75% before AAC renegotiated these contracts.

Productivity was very low and a very large number of people were present at Site creating very difficult conditions from the point of view of both human resource administration and work management. The manpower peak reached more than 10,000 persons present at Site.

Poor tooling and equipment and inadequate working methods and conditions contributed to low production. Many non conformances were open due to the lack of good workmanship.

New construction contracts were negotiated by AAC by the end of 1991 and new contracts were signed under the free market approach. Main emphasis was on productivity, social conditions, contractor's organizations, work verification and acceptance and payment conditions.

Negotiations with the Contractors for new contracts were long and exhausting. The basic concepts for establishing these contracts were time and quality. The new criteria of economical competition had to be explained. Cost breakdown structure examples were prepared and distributed for discussion and comments. The establishment of a relative climate of "credibility between the parties" was the main element in the positive finalization of the negotiations.

New contracts were signed with nine Construction Contractors and work is being assigned to the Contractors through Work Packages prepared with the following purposes:

* define exactly the scope of work;
* verify existence of design documents at Site;
* verify materials availability and sourcing;
* identify construction and interfacing constraints;
* monitor the progress in an objective way;
* downpayment for the material to be supplied;
* rapid payment to the contractors for the work done and accepted;
* avoid finance overloads for the Contractor.

The Work Packages preparation progressed very well, but the following difficulties had to be overcome:
• Assembling the necessary technical documents for the work to be done including the non conformances and site dispositions;
• Getting an agreement on the manhours estimation for each Work Package. The previous productivity levels used in Romania were very low, representing almost 10 times over the international standards. AAC prepared its own estimation and discussed them with the Contractors. Some relaxation on the international standards had to be accepted, and a factor of 2 to 3 times over these standards was finally agreed upon due to the Romanian working methods, tooling and organization.
• Getting an agreement on the rates, for direct manpower and especially for the indirect manpower. In this latter case, many considerations are to be taken into account, ranging from the large overheads to the social costs for the improvement of workers living conditions.
• Recognition of laws and regulations requirements, which posed an overwhelming burden for the Expatriate staff. The old laws are being changed for new ones due to the political changes experienced in the latest years and the transition from communist to a free market economy.
• Making the Contractors responsible, encouraging them to abandon the passive approach which they had adopted previously under the hypothesis that the Client was always prepared to help them to survive and to forgive the lack of quality, the delays and the cost overruns.

Some good results were achieved after the lengthy discussions and Work Package agreements were reached:
- manhours estimations were agreed, and in some cases the Contractors performed better than the agreed standards;
- some tooling bought in Canada and in Italy was lent to the Contractors improving efficiency;
- modifications in the Contractors' organizations induced by AAC produced a reduction in the overall indirect/direct manpower ratio from 75\% to 50\%, with a descending trend still not finished;
- payment flow improved and the Contractors received timely payment for work inspected and accepted.

In addition, important improvements in efficiency are expected through the reorganization of all the Contractors who are working in the Cernavoda Project and some indications have already been observed.
8. ROMANIAN STAFF TRAINING

Operations Personnel

The first group of 19 trainees (from a total of about 100) were chosen and sent for training to Point Lepreau G.S. in Canada, where they have begun an intensive program of system, equipment principles, skills and simulator training.

This first group is expected to form the nucleus of future Romanian Shift Supervisors and Control Room Operators.

The second group of trainees consisting of 28 Technical and Maintenance staff left Romania on May.04 also for training at Point Lepreau G.S.

For Romanian staff not destined to go to Canada for training it is proposed to produce individual training programs detailing both proposed future requirements as well as completed training. The first preliminary steps of this process have begun.

Project Management Team

All the Romanian staff attached to AAC is receiving intensive on-the-job training through exposure to day to day project related activities supervised and guided by the Expatriate staff.

Discussion sessions with Romanian staff were done by Expatriates to improve working methodologies and to make clear the concepts of quality, efficiency and team approach.

The main areas for development are:

♦ Overall exposure to modern project management techniques;

♦ Computer hardware/software familiarization, with extensive applications of word processing, spreadsheets, data base, planning software and drawing applications;

♦ Improving the organizational, administrative and secretarial skills;

♦ Inducing a new mentality based on initiative, creativity and willingness to assume responsibilities.

♦ Establishing friendly relationships among different Romanian staff to encourage the team work approach.
9. QUALITY ASSURANCE PROGRAM

The AAC Quality Assurance Manual was prepared taking into account the in-depth immersion of AECL and ANSALDO in the Romanian quality environment from the previous years.


During this period, RENEL QA Manual covered the AAC activities in the Project and their procedures were applied in an interim basis.

To be fully qualified to operate under the Romanian laws and regulations, AAC must develop and implement functional procedures.
In that regard, 70 were defined in the AAC QA Manual, but after several operative months, AAC Management felt the need of more procedures to define interfaces and methodologies.

Currently 109 procedures has to be prepared and sent for approval to RENEL covering the following areas:
- Project Management and Planning;
- Quality Assurance;
- Industrial Safety;
- Resident Engineering and Quality Surveillance;
- Construction and Installation;
- Services, including Material Management and Procurement, Financing, Budgeting and Administrative Matters.

To date 35 procedures are ready for presentation to RENEL and the rest are in preparation.
In some way this activity implies the qualification of a new organization (AAC) backed-up with the experience of AECL and ANSALDO in the nuclear business.

An important function is the overall supervision of the Contractors' QA Programs. At the moment of the Project take-over by AAC, most of the Contractors had a QA Program in place with Manuals and Procedures approved by the Romanian Authorities. The concepts were understood and the QA requirements posed no mystery for the Romanian specialists.

The main problems arose in the applications of the concepts and the procedures to the practical activities in the office (site engineering, certifications) and in the field (prefabrication, materials traceability, welding, installation).

Corrective actions reports were distributed generously by AAC over the different Contractors during 1991 (summing to 343), of which 91% were closed and 9% are still open.
In addition to that, AAC QA enforced the application of the individual QA Programs in each of the Contractors' QA Departments, in a way that 554 internal corrective action reports were issued internally in 1991. 97% of that total were closed and just 3% remained open to date.

During 1992 the corrective action reports issued by AAC are 43 (closed 37%) and those issued internally by the Contractors are 168 (closed 70%).

RENEL delegated to AAC the Quality Assurance activities for the Romanian Supply for all the Units. The previous liaison office of AECL in Bucharest was converted to a Procurement Quality Assurance group and took over these responsibilities from the Romanian organization.

A complete review of all the past orders started and an analysis of the quality characteristics of each supplier is on-going. Classification of the purchase orders placed previously, suppliers items to be delivered and items in production, raw material availability and other aspects are components of the task assigned by RENEL to AAC.

10. RESOLUTION OF MATERIAL/TOOLING SHORTAGES

Material shortages represented an acute problem for the Project progress. Lack of availability of materials from Romanian sources imposed severe constraints in the latest years due to:

♦ lack of raw material;
♦ quality related matters;
♦ changes in manufacturers' product orientation;
♦ lack of internal financing;
♦ lack of currency.

The material shortages that AAC identified since August 1991 comprises:

♦ nuclear stainless steel piping and fittings;
♦ carbon steel piping and fittings;
♦ piping hangers and supports;
♦ small diameter valves;
♦ cable trays, conduits and accessories;
♦ junction boxes for electrical installation;
♦ high voltage electrical cables;
♦ instruments;
♦ filling compound for civil structures;
♦ miscellaneous material (bolts, nuts, gaskets).

The resolution of material shortages was based on the issuance of Work Orders for procurement in Canada, Italy and Romania.
One of the main advantages of the new RENEL-AAC Contract is the possibility to open the door for importing to Romania necessary goods and services.

A brief summary of the number of Work Orders issued is:

- Canadian Series 160
- Italian Series 73
- Romanian Series 203
- AECL-ANSALDO Series 11
- Engineering Series 150
- Romanian Contract Series 4

**Total 601**

Many difficulties were found in the resolution of the material shortages. To establish a new procurement organization at Site required some time to be operative. The international transportation aspects have to be analysed and some decisions taken in relation to carrier selection and custom clearance. The Romanian organization for import had to be incorporated to the procurement process.

To the present date, some improvements are still necessary to have the right materials at Site in the right time.

The quality and dependability of Romanian suppliers posed a question mark in the procurement aspects. Their willingness to supply is not always accompanied by the quality and time factors and this is a main reason for purchasing abroad goods that could be purchased in Romania.

For example, emergency procurement of electrodes had to be done in Canada to allow welding to continue after a batch of Romanian electrodes was found not acceptable due to poor fabrication process and quality control.

AAC implemented at Site the CANDU Materials Management System, CMMS, developed by AECL as an useful tool for handling inventory, shortages, receptions, requisitions, purchase orders and for sorting of material information in different ways to satisfy multiple users. The CMMS is assisting greatly the growing procurement and material management activities of AAC.

An assessment of the installation tooling and equipment status has been performed by AAC to identify the requirements to achieve scheduled production output. Obsolete equipment and poor quality tools used by the local Contractors were a big impediment to the Project progress. Typical examples are:

- Expansion anchors installation tools;
- Welding machines both for piping and tubing;
- Tube and conduit benders;
- Cable pullers;
- Grinders;
- General tooling.
As in the case of materials, the resolution of tooling and equipment shortages was achieved through the issuance of the necessary Work Orders. Some deliveries of tools have been done and were incorporated rapidly into the production process. Other needs still must be identified.

11. PRE-OSART RECOMMENDATIONS

In October 1990, a group of specialists from the International Atomic Energy Agency, IAEA, performed a PRE-OSART mission in the Cernavoda Project.

The mission resulted in numerous findings pointed out by the specialists and a series of recommendations (total 167) were issued to RENEL.

The main areas of concern were:

- Project Direction, overall organization, interfaces;
- Engineering, general reorganization of engineering companies;
- Construction, working procedures, working methods;
- Services and Contracts;
- Contractors organization, workers living conditions, material handling, shops, tooling, equipment, instruments;
- Quality Assurance;
- Safety, working conditions, safety elements;
- Planning and Scheduling.

An analysis of the PRE-OSART recommendations was performed by AAC Management and a closure program was prepared. To date 67 of the recommendations were closed and closure dates were forecast for the rest of the recommendations.

The follow-up PRE-OSART mission was scheduled for May 1993 but RENEL and AAC will present a request to advance the mission to September 1992 due to the good progress reached in most of the areas.

12. GOVERNMENT SOCIAL PROGRAM

In order to support the completion of the construction of the Cernavoda Project and to allow the operation of its Units, the Romanian Government established a Social Program aimed to improve the quality of life for the Romanian staff assigned to the Project.

Cernavoda was a very small town before the Project started. Many apartments were built for the Client staff and the Contractors workers. Unfortunately, many infrastructure aspects were not solved and the actual living conditions in Cernavoda remain less than ideal for many of the project personnel.
This fact results in high rotation of workers and the exodus of the more qualified staff to other places.

In addition, the need to have the Plant operators living in a satisfactory environment was carefully assessed and the grounds for the Social Program were defined consequently.

The Government Social Program for Cernavoda comprises 21 Projects:

- Water supply plant;
- Sewage treatment plant;
- Heating system;
- Road and bridge over the water channel;
- Road to the port, old hospital and town;
- Hospital 100 beds;
- High school energy profile;
- Primary school;
- Kindergarten;
- Library;
- Food store;
- Agro-market;
- General department store;
- Cinema;
- Recreation centre;
- Motel 120 rooms;
- Housing 400 Apartments in Cernavoda, for Contractors and support organization staff;
- Housing 800 Apartments in Cernavoda, for operations staff;
- Housing 112 Apartments in Constanza;
- Apartment repairs;
- Demolition and renovation of old housing.

Some of the Projects are in execution and close follow-up is ongoing to avoid delays in the completion dates.

For those Projects which are in the approval process, significant delays have been experienced due to the nature of the process which must be followed through the different Ministries and Government Offices.

Many discussions were held in relation to the technical and economic solutions for each Project. Each intervening Officer had the right to present unnecessary comments and hold-ups that postponed the approval of the Project in that particular Office.

The inflationary process modified the budget for each individual project several times and the approval limits of RENEL and the Ministry of Industry were exceeded, the result being that all the non approved Projects must be approved by the Government again.
13. CURRENT PROJECT STATUS

13.1. General information

The following breakdown gives an approximate picture of the construction status of the Project:

- **UNIT 1:** Civil 91%
  - Mechanical 63%
  - Electrical 15%
- **UNIT 2:** Civil 80%
  - Mechanical 5%
- **UNIT 3:** Civil 70%
- **UNIT 4:** Civil 60%
- **UNIT 5:** Civil 50%

**COMMON SERVICES:**
- Pumphouse
  - Civil 90%
  - Mechanical 80%
  - Electrical 50%
- Switchyard
  - Civil 95%
  - Electrical 80%
- Other: (Demin Water Plant, Auxiliary Steam)
  - Civil 95%
  - Mechanical 95%
  - Electrical 95%

Many components for the Unit 2 are actually in Site Warehouses and major components for Unit 3 are in the manufacturing stage.

13.2. Other information about the status of Unit 1

a) The following milestones have been achieved during the AAC management of the Project:

- The post-tensioning of the Reactor Building Containment has been completed ahead of the schedule established;

- The Reactor Building Integrity Pressure Test has been performed with satisfactory results in accordance with the schedule established;

- The condenser was completed from the hardware point of view and hydro tested (shell side) with satisfactory results in accordance with the schedule;
• The successful staffing of much of the project management team.

• The initiation of a comprehensive training program for Romanian operating staff.

b) Complete agreement was reached with 8 Contractors out of 9 in relation to the manhours estimation and the pricing for their relative jobs.

c) Most of the more important mechanical components are installed: steam generators, moderator heat exchangers, pressurizer, degasser condenser, primary and moderator pumps bowls, etc.
A completion & verification program is on-going for all the process components.

d) The turbine/generator was partly assembled in previous years and disassembled for conservation purposes. A program to reassemble the turbine was put in place by AAC and now the high pressure stage is ready to be closed. The other stages will follow.

e) A program for the installation of the Reactivity Mechanisms was prepared complying with all the stringent requirements imposed by the technical documents.

f) Piping systems are advanced both in nuclear and conventional areas. The main problem is posed by lack of supports and hangers installation. Also, completion of the systems preparing them for pressure test is an on-going activity. Some delays by the Contractors in understanding the philosophy of system completion are being resolved by AAC Construction organization.

g) The ventilations systems are 90% complete but many final completion activities have to be performed, including preservation. A major task is to have these systems ready before the next winter to use them for temporary heating in the Buildings.

h) The electrical installation is progressing slowly due to engineering and materials constraints. Major Work Orders were placed in Canada, Italy and Romania and deliveries are expected after June end.
As a result of the cable pulling review program, 15000m of cable were pulled by AAC in the Nuclear Steam Plant area.

i) 75 Engineering Work Packages (EWWs) were agreed, approved and issued to the RENEL design organization (ISPE). 40 more will be issued shortly.
In addition, a Full Scope Simulator is being purchased for training purposes.
14. CONCLUSION

Much has been achieved since the project came under AAC control in August 1991. However much remains to be done. Not the least of the challenges facing the consortium is to change the "mind set" and work methods which have been established by many years of working under the previous centralized economic system.
EASTERN EUROPE INITIATIVES

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INTRODUCTION

Eastern Europe represents a growing energy market for electricity, including nuclear. With the long-term presence of the CANDU system in Romania and the association in the Netherlands and in Hungary, AECL is positioned for growth in the 90s in several East European countries. With its partners, such as Ansaldo, Italy in Romania and the Dutch potentially in Hungary and other countries, AECL is undertaking marketing initiatives in the CIS -- the Commonwealth of Independent States, namely Russia, the Baltics, Ukraine and Hungary. The CIS countries are included because of the potentially large nuclear market, especially in Russia, and because of the energy-related inter-relationships between the CIS and other potential markets in Eastern Europe.

The emerging energy, political and economic trends in these countries are examined and the initiatives that exist for Canadian and international companies with AECL. The Netherlands, although not part of Eastern Europe, represents AECL's long-established presence in Europe and our linkage with Eastern Europe. Because it is AECL's gateway into Eastern Europe, a brief overview on the Netherlands will be provided at the start of the countries section to set the stage for the rest of AECL's initiatives in Europe.

BACKGROUND

The 1990s have seen a great many changes in Eastern Europe, including its energy market. As the countries strive for free market systems, they are coping with uncertain CIS oil and gas imports being charged in hard currency prices, and attempting to rationalize and privatize their energy suppliers.

These trends are evidenced in recent (1990) electricity figures for Eastern Europe:

- Total electricity over the 1989-90 period fell 10%, due to decreased demand with the move to free market economies.

- Nuclear production dropped 15% in 1990, compared to the previous year. This was primarily due to Germany closing down its VVER plants.
Eastern Europe represents a growing market for AECL and its potential Canadian partners, despite the downward trends in the above figures, for several reasons:

ENVIRONMENTAL

Growing concern exists in these countries over meeting EC environmental standards, regarding SO₂ (sulphur dioxide) and NOₓ (nitrous) emissions. Furthermore, much of the coal in these countries is a poor-grade, soft coal, which produces higher levels of pollutants, thereby contributing to the environmental problems.

- Aging generation and replacement of fossil (lignite, coal) of base load plants.
- Treaty obligations, especially for potential EC membership.

CIS - RELATED ISSUES

Because of their former and current heavy reliance on CIS imports, the Eastern European countries are experiencing increasing concern over stability of Russian exports of oil, gas and electricity. Other factors include:

- Safety concerns with RBMK nuclear plants.
- Possible termination of spent fuel takebacks by CIS.

POLITICAL ISSUES

With the move to larger trading blocs, such as the EC, European countries are seeking to forge links with Western countries:

- Seeking Western expertise, especially in privatization and energy conservation methods.
- Seeking Western funding due to collapse of COMECON/clearing accounts.
- Forging links with Western countries e.g., EC, Canada, U.S.

Canada is poised for potential success in this market, despite the major competitive challenges present in Eastern Europe, and the window of opportunity being tight. Canada is viewed as a medium level power and potential partner with strong cultural and political ties with many Eastern Europe countries. In addition, Canadian government and international financial support may be forthcoming for certain initiatives:

- EC funding for the Western Consortium
  A consortium of countries—5 Western EC countries and 3 non-EC countries, including Canada—has been formed to respond to an invitation by RDIEP—Research Development Institute of Power Engineering (NIKIEB) in Russia. EC funding has been committed
to this initiative and is due shortly. Along with an Eastern Consortium of various Russian Institutes, ten study groups have been formed to study together the RBMK reactor design to improve its safety for the next ten years until replacements can be built. An AECL representative heads one of the study groups on Engineering Quality.

- Canada-Hungary Energy Task Force
  Canadian government support exists for specific energy initiatives, such as a review of the Canadian Environmental Assessment process with Hungarians.

- Canadian government financing possibilities
  e.g. EDC funding for Romania Cernavoda 1.

COUNTRIES

AECL's activities in its current European bases of the Netherlands and Romania will be highlighted first, followed by a description of the opportunities and initiatives in its emerging markets, including:

- Russia
- Baltics (Latvia, Estonia, Lithuania)
- Ukraine
- Hungary

Netherlands

The Hague office, established in 1985 is AECL's European focal point. In the course of AECL CANDU's work in the Netherlands, strong relationships have been built with the Dutch industry. Opportunities for joint cooperation on CANDU projects in third countries have been explored. For example, the Dutch are interested in cooperating with AECL CANDU for additional nuclear units in Romania and opportunities in Hungary, including pursuing financing for the proposed Dutch scope.

Canada and the Netherlands have very strong historical ties with each other and also with other countries in Europe. The Netherlands' connection strengthens Canada's European position and brings the solid industrial infrastructure and linkages required for AECL to succeed in the East European market.

Electricity demand in the Netherlands is growing more rapidly than anticipated (an annual rate of increase between 2.5 to 5% versus the 1% assumed for planning purposes) and decisions on new generating capacity are required. The Dutch have a one-unit 50 Mwe BWR nuclear power plant and a 1 × 450 Mwe PWR nuclear power plant, that have been in operation for 23 and 19 years, respectively, and a small research reactor. Although they have both technologies, the Netherlands is still an open market, as
they have not committed yet to any one technology. Nuclear is a potential option for the Netherlands’ long-term energy program and CANDU is an established option; a government commitment to nuclear is expected by mid 1993. The Netherlands would of course provide all the financing for a CANDU plant.

The Dutch launched an extensive design review program (the PINK Program) two and a half years ago to study several nuclear reactor designs, including the CANDU 3 and 6. This is part of their ongoing studies, which now total 24 major studies since 1986. In addition, the Dutch are conducting an extended study comprising a high level, exhaustive technical analysis on CANDU 3 and 6. They are in the midst of the first phase of this 15-month program, which started in January 1992. The scope includes an ongoing series of visits and exchanges with Canada by Dutch scientists and engineers. As a result of the PINK program and its extension, CANDU is one of the short list options for the Netherlands.

Romania

AECL has been active with Cernavoda Unit 1 nuclear power plant since the early 1980s. AECL CANDU and its partner ANSALDO of Italy, who formed a consortium, AAC, signed a contract in August 1991 to provide project management, construction management, commissioning and operations to complete the first CANDU 6 unit at Cernavoda. The Canadian and Italian governments have approved financing of Cdn $300 million and Cdn $170 million, respectively.

AECL CANDU is working very closely with the Romanian utility RENEL and have an integrated team of about 150 Canadians and Italians plus Romanians at site.

Electricity. Romania is faced with an electricity shortage problem. Average generating power was far below 50% of the installed capacity of the country in 1991. Poor load factors are due to the deteriorating condition of their generating plants, poor quality coal and a shortage of oil and gas. Romania had to import 900 Mwe of electricity in 1991 and allow consumption by only certain industries.

1991 Installed Capacity -- 22380 Mwe
- Coal -- 8680 Mwe
- Oil -- 8020 Mwe
- Hydroelectric -- 5680 Mwe

Average generating power -- 6490 Mwe

Opportunity and Issues. Partnering with Europeans and others, ie. Ansaldo of Italy as potential basis for long-term opportunities. The long term opportunity is for nuclear units 2
to 5. Most of the Unit 2 equipment has already been purchased by the Romanians.

Issues include:

- Ability to finance.
- Economic conditions.
- Political stability.
- Localization ability.

AECL's Initiatives. AECL is supporting completion of Unit 1 at Cernavoda by providing project and construction management and some technical expertise to help upgrade the heavy water plant; EDC funding is $300 million for the Canadian portion.

- Private sector participation in Unit 1 completion, e.g., NCM.
- Long-term position with our partners for Cernavoda Units 2 - 5 and other European opportunities.

CIS (Commonwealth of Independent States)

The CIS is undergoing significant political and economic changes that are and will ultimately have far-reaching impacts on its energy sector. The attempted move to world energy prices for exports, charged in hard currencies, has increased its inflation rate and affected its exports to its surrounding neighbours.

Russia

Energy and Electricity. Only electricity and gas production continued to expand in 1990, and even so, at minimal rates. Electricity grew 0.3% in 1990, while average annual growth in the energy sector in 1985-90 was 2.8%.

Due to economic uncertainty after the break-up of Soviet Union, exports of all energy resources declined from the CIS, largely from Russia, in 1991, due to the shift to hard currency and decreased demand:

- Crude oil exports declined by 57 million tonnes or 52% over 1990,
- Petroleum products exports fell by 9 million tonnes or 18%
- Natural gas exports declined by 4.5 billion cu. meters, and
- Electric power exports declined by 17 billion KwH or 47%.
Electricity Breakdown (total figures for CIS shown)

<table>
<thead>
<tr>
<th>Total Installed Capacity</th>
<th>1990</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal (coal, oil or gas fired)</td>
<td>345 Gw</td>
<td>100%</td>
</tr>
<tr>
<td>Combined cycles</td>
<td>146 Gw</td>
<td>42%</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>97 Gw</td>
<td>28%</td>
</tr>
<tr>
<td>Nuclear</td>
<td>67 Gw</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>34 Gw</td>
<td>10%</td>
</tr>
</tbody>
</table>

Nuclear. The dependence of Eastern European countries on Soviet designed and developed reactors is large. There are basically two types of reactors, the pressurized water reactor (known as the VVER) and the graphite-moderated, light water-cooled, channel-type reactor (known as the RBMK).

Russia has 24 nuclear reactors at nine sites with installed capacity of 20,700 Mwe. They are of both VVER and RBMK design, with a cloud hanging over the RBMK design (witness recent Sosnovy Bar incident near St. Petersburg).

Since Chernobyl, Russia has suffered from a tarnished credibility in the nuclear field, both internally and internationally and there is strong European pressure to shutdown and/or upgrade Russian-designed nuclear power plants.

Opportunities and AECL Initiatives. On his recent trip in late May 1992 to Russia, Federal Energy Minister, Mr. Jake Epp, and the Russian Atomic Energy Minister signed an MOU (Memorandum of Understanding) to expand and strengthen mutually beneficial cooperations for the peaceful use of atomic energy.

Over the past year, AECL has established links and information exchange agreements with the Kurchatov Institute in Moscow, Russia's leading atomic energy research body. During Mr. Epp's visit, D. S. Lawson, President of AECL CANDU and E. P. Velikov of the Kurchatov signed an MOU between the Kurchatov Institute and AECL to cover cooperative activities between the two parties, including (among others) the further study of HWRs, development of new heavy water production technologies, the use of nuclear energy for hydrogen production, and the proposed Canada-Russia Safety Engineering Center.

Current opportunities with Kurchatov Institute include:

- HWR (Heavy Water Reactor) Technology
  Using CANDU's common features to the Russian channel reactor design (RBMKs), Canadian participation will improve the Russian's international credibility and offer the Russians potential opportunities to acquire future international business.
• Proposed Canada-Russia Safety Engineering Center

With potential Canadian government support, a Safety Engineering Center has been proposed to integrate about 50 nuclear professionals, from both Canada and Russia to provide an in-depth study of RBMK reactors.

Other AECL initiatives include:

• St. Petersburg international competition -- an international jury is reviewing bids for nuclear power plants; AECL has submitted an indicative proposal for the CANDU 6. The results of the latest session, held May 18-22, 1992, was the judges' rating of all proposals into three groups, ranging from acceptable for construction in Russia on an immediate basis to not meeting the requirements. AECL CANDU's proposal was rated among the top five, in the first group as acceptable.

• Hydrogen project -- AECL is involved with several Canadian firms with significant strengths in the hydrogen technology area. The aim is to use nuclear power to produce electrolytic hydrogen.

• Heavy water sales and development -- The first purchase by Canada was completed earlier this year.

Baltics (Latvia, Lithuania, and Estonia)

Energy and Electricity. All three Baltic regions are facing a severe energy crisis, due to their huge dependence on CIS imports, especially in the primary energy sources and their transition to an independent state. With little indigenous resources of their own, the Baltics are virtually reliant on Russian imports of oil, gas, coal and electricity e.g., Latvia, at the highest, imports more than 90% of its energy from Russia.

Electricity

Electricity Generation 1988 (Gwh)

<table>
<thead>
<tr>
<th>Country</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estonia</td>
<td>17,627</td>
</tr>
<tr>
<td>Latvia</td>
<td>5,110</td>
</tr>
<tr>
<td>Lithuania</td>
<td>29,200</td>
</tr>
</tbody>
</table>

Nuclear. Only Lithuania has nuclear reactors. This station Ignalina is of the RBMK type, with two units at 1380 Mwe each output, installed in the 1980s.

Opportunities and AECL Initiatives. Lithuania needs help in establishing its regulatory system and operating support to ensure safe operation. Ontario Hydro is taking the lead in the utility support work.
AECL has held exploratory discussions with the Lithuanians and may work with the Kurchatov Institute to provide ongoing help to Ignalina. The Ignalina station has under construction a third unit. The BOP is about 50% complete and uses two 750 Mwe turbo-generators. An outline proposal has been submitted by AECL to use two CANDU 6 reactors and connect them to the existing turbo generator sets. The site is physically suited to this arrangement and the location of the present Reactor Building (RBMK) could be used for the CANDU service building. AECL is awaiting a response from the Lithuanians on this proposal.

Ukraine

Nuclear. There are 15 nuclear reactors in five nuclear plants in the Ukraine. Ten of the reactors are of the VVER-1000 type; two are of the VVER-440 type and the remaining three are RBMK-1000s (only two units -- 1 and 3 -- at Chernobyl are currently in working condition).

Opportunities. The Ukraine faces similar nuclear challenges as the other ex-Soviet states. AECL has held some preliminary meetings with the Ukraines to-date. AECL's Vice-President, Projects is on the Review Committee for Chernobyl; the Committee's mandate is to decide how to decommission all units, 1 to 4. AECL has also held exploratory discussions with the Ukraines regarding potential help with the units at Chernobyl.

Hungary

Overview. Hungary is in the midst of a deep recession, grappling with the realities of evolving into a free market system; rising unemployment and decreasing industrial output (which dropped a further 20% in 1991).

Hungary's energy situation is highlighted in detail in this paper as it is one of the main East European countries in transition to a free market economy and less reliance on Russian imports to meet most of its energy needs. Since it relied for generations on secure and relatively cheap energy from the CIS (virtually 65% of its imports) and as Russia moves to charging world prices for energy exports, Hungary has had to focus on developing its own energy policy to become less reliant on imports.

Energy Supply (Production versus Imports) 1990. Domestic production of energy is mainly in the coal and electricity sectors. These two groups produce 80% and 72% of the total, respectively.

- Nuclear represented 25% of total energy production in 1990 (third largest segment).
• Oil and gas are largely imported from the CIS (60% and 55% of total, respectively).

• Hungary will remain reliant on CIS oil imports for the majority of its needs well into the future. Despite the uncertainty and move to hard currency prices, the existing infrastructure links mean Russian oil is likely to remain at least 10% cheaper than OPEC production.

Electricity and Nuclear. The state electricity company, MVMT (Magyar Villamos Muvek Troszt), recently privatized, currently controls 97% of the country's 7 Gw generation market. Demand has fallen at least 3% the past two years as energy-intensive industries closed; however, predictions are that demand will grow again after 1995 by 2 - 2.5% per year, largely from domestic use.

MVMT's production capacity is fairly evenly divided between nuclear, coal and liquid fuels. Highlights of their electricity situation include:

• Paks nuclear station (4 X 440 Mw units) provided 13.5 Twh or 37% of a total of 36.6 TWh in 1991.

• Continues to remain dependent on imports of electricity from the CIS mainly to meet peak demand i.e. 10.5 Twh or some 20% of total demand in 1990.

• Great uncertainty with CIS electricity imports and the cut in imports has reduced grid reliability; MVMT's reserve margins are just 15%. If imports decreased, domestic capacity could not cover peak demand.

Opportunity. Two major opportunities in Hungary are a new baseload plant (coal or nuclear) and assistance with energy conservation and environmental assessment/public information processes. AECL is involved in both of these opportunities.

• New Baseload Plant
MVMT predicts it will need new baseload plant by about the year 2000, but as yet it is unsure how it will be financed or the extent of foreign financing. The requirement is for 1 -1.5 Gw plant(s) fired by either domestic lignite, imported hard coal or nuclear.

• Energy Conservation and Environmental/Public Process
Hungary is aiming for EC Environmental standards. With regard to SO$_2$ and NOx emissions, the government wishes to fulfil its obligations to the Helsinki agreement by the end of 1993. Efforts to reduce SO$_2$ emissions are focused on coal-fired power plants.
Energy conservation is another key focus to reducing the emissions. Currently, Ontario Hydro has a Demand Supply Management contract with MVMT.

**Issues.** The major issue is financing, as Hungary needs to minimize its increase in foreign debt. Hungary's $20 bn foreign debt is the largest in the region and consumes between a quarter and a third of foreign currency earnings.

Another major issue is the coal industry. With spiralling unemployment in the coal sector, there is a strong impetus to maintain as many of the coal mining jobs as possible. This economic reality may affect the coal versus nuclear decision currently faced by Hungary.

Other issues include:
- Maximize local content.
- Nuclear waste management—how and where to dispose of it.
- Public opinion/acceptance.
- Safety-related issues to nuclear.

**AECL's Initiatives.** AECL CANDU submitted an indicative proposal for the CANDU 3 in October 1991. Major features of the proposal include:

- Smaller incremental capacity; potentially easier to finance.
- Maximize local content.
- Bring in European supply partners e.g., John Brown, Netherlands.

AECL CANDU facilitated setting up the Canada - Hungary Energy Task Force, a government-to-government committee implemented at the start of this year. The mandate of the Task Force is to share information on Canada's Environmental Assessment process with the Hungarians. The first meeting in Canada was held in early May, 1992. Task force members include ex-Canadian government officials and Hungarian energy and economic experts. The timeframe for completion is mid-1992.

**SUMMARY**

To succeed in these markets, AECL CANDU and its partners must understand the key success factors by country, as they vary from technical to economic/financing solutions.

At a minimum, CANDU must have competitive economics as compared to the other energy options these countries are examining, such as oil, gas and combined cycle.

Partnerships and alliances with many players, both Canadian and international is another critical factor. Not only is their potential financing a requisite, but their expertise and skills
to meet the many needs of our clients. These needs range from technical and management expertise to overall processes, such as privatization and environmental assessment concerns.

Financing at both the Canadian and international level is another requirement. Different partners and approaches to this dilemma will allow CANDU to continue competing in some of these markets, faced with economic crises.

Funding for such initiatives as the Western Consortium and the Canada-Hungary Energy Task Force allow Canada to demonstrate its willingness to support change in Eastern Europe. Such Canadian Government support is vital for these type of initiatives so as to position the introduction of CANDU into these emerging markets.
SESSION 3

CANADIAN USED FUEL MANAGEMENT PROGRAM

SESSION CHAIRMAN

Michael Burt
University of New Brunswick
The Canadian Nuclear Fuel Waste Management Program (CNFWMP) was launched in 1978 as a joint initiative by the governments of Canada and Ontario. Under the program AECL has been developing and assessing a concept to dispose of nuclear fuel wastes in plutonic rock of the Canadian Shield. Ontario Hydro has advanced the technologies for interim storage and transportation of used fuel. In 1981 the two governments stated that selection of a nuclear fuel waste disposal site would not proceed until the concept had been reviewed and assessed. Thus the concept that has been developed is generic rather than site-specific.

The concept is to isolate the fuel waste from the biosphere by a series of engineered and natural barriers. These include the waste form, container, buffer and backfill, and the host rock. During the past fourteen years AECL has carried out detailed studies on each component of this multi-barrier system. A robust concept has been developed, with options for the choices of materials and designs for the different components.

The disposal concept has been referred for review under the Canadian Environmental Assessment and Review Process (EARP). AECL is the "Proponent" for this review, and will submit an Environmental Impact Statement (EIS) describing the concept. The EIS will be written to conform with guidelines issued by the Environmental Assessment Panel responsible for carrying out the review. Hearings will be held at which members of the public will have an opportunity to make presentations to the Panel and to question AECL. The hearings will take place in those provinces with a particular interest in the concept and its application, including Ontario, Quebec, New Brunswick, Manitoba and Saskatchewan. At the end of the review the Panel will make recommendations on the acceptability of the concept and for future action on nuclear fuel waste disposal. Government decisions are then anticipated on the next steps to be taken.

The Panel conducting this review was appointed in late 1989. Public Open Houses were held in the spring of 1990 to acquaint prospective participants on how to enter the process. Scoping Sessions to assist the Panel in determining the scope of the EIS, took place in the autumn of 1990. Major issues raised included arguments for and against storage as opposed to disposal, the adequacy of the regulatory criteria, and issues of monitoring and retrievability. In response to aboriginal concerns, an aboriginal representative was appointed to the Panel.
In June 1991 the Panel issued for comment a set of draft guidelines for the EIS. Comments were received from over thirty different groups and individuals. The final guidelines were issued in March 1992, and we expect to submit our EIS to the Panel in 1993.

Ethical issues associated with the management of nuclear fuel wastes were of considerable concern to the participants during the Scoping Sessions. An AECL workshop to address the ethical issues related to the concept provided useful perspectives on the key issues and advice on approaches to addressing these issues.

The future direction of the CNFWM program will depend on the recommendations of the Panel and the resulting governmental decisions on the appropriate next steps. AECL and Ontario Hydro have initiated planning to be in a position to proceed with implementation if the disposal concept is approved. If the concept review is completed by 1995, as currently expected, and if the concept is approved, disposal would not begin before about 2025.

INTRODUCTION

In responsible industrial societies, nuclear fuel waste management has been handled with a degree of care and consideration for protection of human health and the environment not generally applied to other wastes. This is a consequence of the industry's recognition, from the very beginning, of the hazardous nature of the waste, and of the need to manage the attendant risk.

The volume of nuclear fuel waste in Canada is relatively small. The used fuel is being safely stored, and many years of experience have been accumulated with both pool storage and dry storage systems, backed up by supporting R&D which indicates that these practices can be safely continued for many decades to come(1,2).

However recognition of the need to provide for long-term safe management led to a decision by the governments of Canada and Ontario, in 1978, to establish the Canadian Nuclear Fuel Waste Management Program (CNFWMP). The objective of the program was to investigate the safety, security, and desirability of a concept for the long-term management of nuclear fuel waste. The concept consists of permanent disposal in a deep underground repository in intrusive igneous (plutonic) rock(3). Disposal is defined as a permanent method of management in which there is no intention to retrieve the waste or handle it further in the future. The incentive for disposal is based on the ethical principle that we, as the principal beneficiaries of current nuclear energy generation, should assume to the extent possible the burden for managing the waste. This means among other things:
- providing the financial resources for managing the waste, and Canada's nuclear utilities are making financial provisions for doing so, and
- developing the technology for the long-term management of the waste, technology that ensures the long-term protection of human health and the environment, and that, to the extent possible, does not rely on long-term institutional controls.

In 1981 the two governments re-affirmed their commitment to the program, but announced that no disposal site selection would be undertaken until the concept had been reviewed and accepted(4). Thus, to date, the R&D program and concept development have been carried out to date on a generic basis rather than a specific project basis.

Participants in the program have included AECL, which is the lead agency for research on disposal; Ontario Hydro, which has advanced the technologies for storage and transportation; Energy, Mines and Resources (EMR) Canada; Environment Canada; scientists at Canadian universities; and consultants in the private sector. AECL's activities are cofunded by AECL and Ontario Hydro through the Candu Owners' Group (COG).

THE DISPOSAL CONCEPT

The concept is based on disposal in the plutonic rock of the Canadian Shield, which extends through a large part of Canada from western Quebec through to Saskatchewan. The fuel waste will be isolated from the biosphere by a series of engineered and natural barriers.

During the past fourteen years we have carried out detailed studies on the components of this multiple barrier system. The objective has been to develop a concept with flexibility in choice of methods, materials and designs for the components of the disposal system. The approach has focused on ensuring the performance of the system as a whole rather than specifying performance requirements for individual components. The main elements of the concept include enclosing the fuel waste in corrosion resistant containers, emplacing these containers in a vault excavated 500-1000 meters deep in plutonic rock of the Canadian Shield, the use of buffer materials to retard the flow of water and radioactive materials, and the use of seals and buffer material to backfill the vault and access shafts and tunnels.

The R&D program has covered a broad spectrum of activities(5). Basic and underlying research has been conducted to achieve a fundamental understanding of the various phenomena that may occur in a disposal vault. Integrated experiments and studies of natural analogues have been carried out to determine the interactions among these phenomena. There has been extensive
field work to characterize the hydrology, chemistry, lithology and structural properties of plutonic rock. Field and laboratory studies have examined the movement of substances through the biosphere and the effects of radiation on biota. Ontario Hydro has assessed the environmental, economic and social impacts of an operating disposal facility and transportation of waste to it.

An Underground Research Laboratory (URL) has been constructed to carry out large-scale, in-situ experiments in plutonic rock of the type expected to be suitable for disposal. This was the first such test facility to be built below the water table in previously undisturbed granitic rock, and disturbance to pre-existing conditions caused by construction has been continuously studied and recorded. Construction of such a facility was strongly recommended by the technical oversight committees for the program, to provide for development of excavation and characterization methodology and to conduct underground testing. We are carrying out a long-term program to develop and test components and rock behaviour under conditions representative of a vault environment, as well as methods for emplacing buffer, backfill and vault seals.

The choice of methods, materials, and designs for an actual disposal system will ultimately be made on the basis of performance, availability, cost, and practicality. They could include, for example:

- the form of the waste: used fuel bundles or glass;
- the disposal container material: titanium alloy, copper, or other durable material;
- the container design;
- the composition of materials used for the buffer, backfill, and seals;
- the excavation method: blasting or boring;
- the depth, geometry, and the number of levels of the vault;
- the size and shape of the excavated openings; and
- the location of the waste containers: within disposal rooms or in boreholes in the floor of the rooms.

These choices will not be made until a site for a repository has been selected.

ENVIRONMENTAL REVIEW

As the initiating department, Energy, Mines and Resources (EMR) has referred the concept for review under the Canadian Environmental Assessment and Review Process (EARP). AECL is the "Proponent" for this review and will submit an Environmental Impact Statement (EIS) describing the concept. The Environmental Assessment Panel responsible for carrying out the review is chaired by Mr. Blair Seaborn. The Panel has appointed a Scientific Review Group (SRG), chaired by Professor Raymond Price and composed of 14 eminent scientists from a variety of
relevant disciplines, to assist it in judging the technical validity and acceptability of the disposal concept. The Federal Environmental Assessment Review Office (FEARO) provides administrative support.

The Panel will review AECL's concept, along with a broad range of nuclear fuel waste management issues. These include the criteria for determining safety and acceptability; the approaches used in handling wastes both in Canada and other countries; the potential social, economic and environmental effects of waste disposal; and the potential impact of recycling and other processes on waste volume. A general review of other aspects of the nuclear industry, such as energy policy and reactor operation and safety, is specifically excluded from the Panel's review.

Following submission of the EIS, the Panel will review the EIS to ensure that it meets the requirements of the guidelines. A deficiency statement would be issued if there were any issues judged not to have been adequately covered. Once all the required information has been provided, public hearings will be held at which members of the public will have an opportunity to make presentations to the Panel and to question AECL. The Panel is administering the allocation of $750,000 provided by AECL to support effective participation by the public in this process. It is expected that all federal departments with a relevant interest, e.g. Atomic Energy Control Board (AECB), EMR, Environment, Health and Welfare, and Transport, will participate in the review. Environment Canada has assembled two teams of experts to carry out a detailed review of the concept, to assess its ability to protect the environment. At the end of the review the Panel will make recommendations on the acceptability of the concept and for future action on nuclear fuel waste disposal. Government decisions on the next steps to be taken are then anticipated.

In the spring of 1990 FEARO organized a series of "Open Houses" to inform interested parties, not directly connected with the nuclear industry or with the scientific review process, about how they could take part in the review. "Scoping Hearings" took place in the autumn of 1990 to identify issues of concern and thereby assist the Panel in setting guidelines for the scope of the EIS. These hearings provided the first opportunity for interested parties to become directly involved with the program as "participants". In total, 130 participants made presentations: they included government departments, scientific and business organisations, special interest groups, and private individuals. A number of major issues were raised. These included arguments for and against storage as opposed to disposal, the adequacy of the regulatory criteria and issues of monitoring and retrievability, etc. Aboriginal land claims affect much of the land where there are potential sites and the concerns of aboriginals were raised by their representatives. In response, an aboriginal representative was appointed to the Panel.
In June 1991 the Panel issued draft EIS guidelines for comment. Comments were received from over thirty different groups and individuals. The final guidelines were issued in March of 1992(6).

AECL expects to submit the EIS in September or October of 1993 and, assuming that there are no major deficiencies, we expect that public hearings will take place during 1994, and that the Panel will issue its report towards the end of 1995.

Several aspects of the Panel’s review are unique or unusual, and may well challenge the traditional assessment review process:

- A concept for disposal is being submitted for review, rather than a site- and design-specific project.

- Choices are being called for on matters important primarily to future generations.

- The primary purpose of disposal is to ensure protection of human health and the environment should societal controls cease to be effective.

- There is a conflict between the desire of some parties that detailed technical criteria for acceptability be set now, and the need to retain maximum flexibility at this point to minimize the constraints on later decision-making when the decision is taken to begin disposal.

Traditional environmental reviews focus on location- and project-specific concerns involving community and environmental impacts, project organization, design specifications and alternatives. Although the case studies we have performed assist in addressing such questions, the extent to which these issues can be dealt with during the current review is limited.

It is clear that impacts of a facility cannot be fully addressed independently of the details of specific site and design characteristics. The best that likely can be achieved is to use currently available information and hypothetical site and design characteristics to indicate that the concept could be implemented with present technology, that an actual disposal system can be assessed, and that a suitable site can likely be found in Canada. The last point will require a considerable degree of judgment, since no specific site can be put forward during this review.

We believe that we have developed a safe and acceptable technology for disposal. Because detailed, complex and broadly based questions are involved, we expect substantial scientific debate as the review proceeds. Such scientific debate is healthy and ultimately will be of immense benefit to achieving the program objective of safe, responsible disposal of fuel. But the Panel will have a significant task ahead of them in assimilating this debate. The SRG will play a very important role.
AECL views the current review as the beginning of a continuing process. In developing and applying the technology for managing disposal, there will be a need for further reviews, and public consultation and involvement. Any facility will be subject to rigorous regulatory criteria, and society will demand that a step-by-step process be followed. Thus a decision to proceed resulting from the current review would not commit society irrevocably. A judgement now that the concept is safe and acceptable would represent only the first of a series of decisions between distinct phases of the process.

Each phase should lead to increased confidence in the overall system, sufficient confidence to permit a decision to proceed to the next phase. We are currently nearing the end of the first phase - concept development and assessment. If the Panel share our view that we are far enough along the development path, this should lead to a governmental decision to proceed with site-specific activities at the appropriate time, beginning with site screening:

- site screening would lead to the selection of one or more sites for detailed characterization based on surface techniques;

- such site characterization studies would lead to a selection of one or more sites for exploratory excavation and more extensive in-ground characterization;

- in-ground characterization could lead to a decision to initiate design, construction and operation of a repository, probably beginning with a demonstration phase;

- design, construction and operation of a facility would involve on-going review, reassessment and re-commitment, leading to continued operation and then eventually to a decision to cease operations and to decommission;

- decommissioning and post-operational monitoring would ultimately lead to a decision to close and seal the repository.

The process of evaluating specific sites will likely involve a further ten to fifteen years of work before a commitment would be made to initiate an underground excavation, followed by a further ten to fifteen years of site exploration and characterization before construction could begin. Thus waste would not begin to be placed in a repository before about 2025. By then one would have accumulated many years of site-specific data and a series of increasingly refined evaluations on which to base a decision to begin to emplace waste.

The decision to close and seal the repository would be made taking into account all the accumulated evidence and experience gained throughout the siting, characterization and operational
phases, a process extending over close to a century. Only with that decision will the concept have been definitively judged as safe and acceptable.

Thus at the current concept assessment phase of the process, "concept approval" does not mean that definitive responses are available for all technical and social issues, since all such issues will not have been resolved. The concept has been developed specifically to be able to accommodate the different conditions and demands that will be specific to particular sites. Rather, concept approval represents a judgment that:

- sufficient understanding has been developed to continue with the process, with an expectation that we will eventually reach the end point of sealing a repository; and that

- at the appropriate time we should proceed to the next phase of the program, the beginning of site-specific activities.

ESTABLISHING CONCEPT ACCEPTABILITY

The AECB has set out objectives and criteria for the disposal of radioactive wastes at a specific site in a series of regulatory policy statements\(^7\,8\,9\). The development program we have carried out over the past fourteen years has enabled us to develop the tools and expertise needed to obtain site-specific data and to incorporate this information into a repository design that will meet these regulatory criteria.

To demonstrate this, we intend to show that:

- technology exists to site, design, construct, operate, decommission and close a disposal facility that meets the regulatory requirements for protection of human health and the environment;

- a methodology is available to evaluate the performance of a disposal system in plutonic rock in terms of regulatory requirements for the protection of human health and the environment; and

- it is likely that a suitable site can be found in Canada.

Because of the governments' requirement that no site be selected prior to review and acceptance of the concept, AECL has not assessed a specific site with its particular body of rock and its particular surface environment. Rather, three related case studies have been performed, each with its own objectives relative to the assessment:

- We have developed a conceptual design of a hypothetical disposal facility. This design was used to assess engineering
feasibility and costs, and to provide information relevant to assessing the potential impacts of disposal.

- Ontario Hydro has assessed the short-term (preclosure) impacts of implementing the conceptual design at a hypothetical site. The objectives were to demonstrate the assessment methods, determine how sensitive the estimated impacts are to changes in the factors considered, and indicate the type and magnitude of impacts that could occur.

- We have assessed the long-term (postclosure) impacts of a hypothetical disposal facility at a hypothetical site having subsurface characteristics derived from information obtained from a field research area. The objectives were to demonstrate the assessment methods we have developed, demonstrate how the assessment methods are used as a design tool to determine design constraints, and establish the relative importance of various design parameters, determine how sensitive the estimated impacts are to changes in the factors considered, and show that a disposal system, under hypothetical but realistic conditions, could meet the safety criteria.

Thus, in our development program we have demonstrated our ability to investigate the surface and subsurface characteristics of potential host rock formations, we have demonstrated specific aspects important to the engineering of a disposal system, and we have developed a conceptual design of a hypothetical disposal facility.

While it is not possible to provide complete full-scale demonstrations of all aspects of a disposal facility without actually building one, our case studies are based on realistic facility and site characteristics, albeit hypothetical, using information obtained from extensive laboratory and field research. The hypothetical disposal facility is technically feasible with available technology or with reasonably achievable developments, as required by the AECl(7), and the characteristics specified for the hypothetical sites are, in our opinion, not exceptional.

While many detailed investigations would have to be done at an actual candidate site to establish its suitability for a waste disposal facility, we will argue that the requirements of a technically suitable site are likely to exist on the Canadian Shield. In the final analysis, acceptance that technically suitable sites exist will require a significant degree of judgment. The validity of that judgment will ultimately be determined by evaluating a specific site (or sites).
ETHICAL ISSUES

Ethical issues are of major importance in the review, and this interest is reflected in the EIS guidelines. The guidelines, for example, state that:

...ethical and moral perspectives, along with various social issues, as evidenced by presentations to the Panel at the scoping meetings, are as important as scientific, technical and economic considerations. The proponent should include ... an investigation of how relatively narrow and focused considerations of a scientific, technical or economic nature should be viewed in the much broader context of ethical, moral and social considerations(6).

It is clearly the responsibility of those charged with the task of handling hazardous wastes of all descriptions to take account of the moral and ethical issues involved. From the beginning, the Canadian Nuclear Fuel Waste Management Program was founded on the ethical principle that we have a responsibility to future generations. To test our beliefs, AECL conducted, in March of 1991, a workshop with eight ethicists, social scientists and theologians, including an aboriginal leader, with expert understanding of the moral and ethical consequences of technological decision-making in Canada, the United States and Sweden. The objectives of the workshop were to provide considered perspectives on the key ethical issues related to the disposal concept, and to provide advice to AECL on the approaches necessary to address the issues identified.

The workshop was highly successful and the discussions were constructive and informative. Disposal was regarded as preferable to storage. The recommendations, broadly stated, were that the generation which benefits from nuclear power must take responsibility for disposing of the resulting fuel waste, but that future generations should have the options of retrieving the waste and of taking remedial action if necessary. In principle these options exist within our concept.

It was regarded as most important that arrangements for handling waste be based on informed consent amongst the affected public, and that developing informed consent should be clearly recognised and distinguished from persuasion. A report summarizing the proceedings of the workshop has been produced(10).

FUTURE DIRECTION

The future direction of the CNFWM program will depend on the recommendations of the Panel and the resulting governmental decisions on the appropriate next steps.
Ontario Hydro has published a Corporate Reference Plan for Used Fuel(11), and AECL and Ontario Hydro have initiated planning to be in a position to proceed with implementation if the concept is approved. Siting activities have been identified as important initial activities. These include site screening, characterization of one or more potential sites using surface techniques, and excavation and in-ground characterization of at least one site. Implementation will require optimization of the concept, and there will be a need for continued R&D in key technologies to support this optimization.

If the review is completed by 1995, as currently expected, and if the concept is approved, disposal would not begin before about 2025. Although this date appears to be far in the future, the many activities associated with siting a facility, optimizing the details of the concept, and public consultation and review processes will require that amount of time. To demonstrate that progress is being made, and to ensure that the expertise developed in the program is retained, it is important that we proceed with implementation as soon as possible, once the concept has been accepted.

CONCLUSION

AECL believes that it has developed a robust and flexible concept for disposal of nuclear fuel waste that will meet the regulatory requirements of Canada. We are continuing research and development work to ensure the public and the industry has as much confidence as possible in the safety of the concept and in the feasibility of implementing it. The process for a federal environmental review of the concept has started.

The review of a concept as opposed to a site- and design-specific project requires turning attention away from project-specific issues normally addressed in an environmental assessment, and towards matters important to judging whether it is appropriate to proceed with the first phase of implementation. We believe that we have reached the stage in the CNFWMP where the greatest benefit from continued activities will result if they are carried out on a site-specific basis.

We are entering a very public process. Our experience has shown us that such processes are not easy for the nuclear industry. We are confident we will provide a sufficiently thorough and convincing EIS that the Panel will recommend entering the next phase of the process leading towards disposal. Our confidence is founded on the strength and depth of our technical program and a well-founded public consultation program. Building on this foundation we can begin to address the many demands that this review will place on us. There is an old Chinese curse that says, "may you live in interesting times." The next few years are going to be very interesting for the Nuclear Fuel Waste Management Program!
REFERENCES


ENVIRONMENTAL ASSESSMENT REVIEW OF THE CONCEPT OF DISPOSAL OF NUCLEAR FUEL WASTE IN CANADA*

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INTRODUCTION

The long-term management of nuclear fuel waste is an important issue to Canadians. For this reason, a public review process is being undertaken to provide the public and scientists the opportunity to examine, and discuss thoroughly the proposed concept of geologic disposal of nuclear fuel waste along with a broad range of nuclear fuel waste management issues. Atomic Energy of Canada Limited (AECL) is the lead agency in the development of the disposal concept.

This review is being conducted under the federal Environmental Assessment and Review Process (EARP). This process, established in 1973 by the Government of Canada, attempts to ensure that:

1. environmental effects are taken into account early in the planning of new federal projects, programs and activities;

2. environmental assessments are carried out for all projects which may have adverse effects on the environment, before commitments or irrevocable decisions are made;

3. the results of these assessments are used in planning, decision-making and implementation.

The environmental assessment and review of the proposed concept of geologic disposal of nuclear fuel waste was initiated in September 1988 by the federal Minister of Energy, Mines and Resources (EMR), the initiating department. He requested the federal Minister of Environment to form an environmental assessment panel to undertake a review of the proposed concept. In making this request, the Minister of EMR noted that this will be one of the most important environmental assessments ever undertaken in this country and will provide an essential foundation for future decisions on energy policy.

The Minister of Environment appointed an environmental assessment panel in October 1989 to review the safety and acceptability of the proposed concept, and to examine the social, economic and environmental implications of a possible nuclear fuel waste

* The views expressed here are strictly the author's own and do not necessarily reflect those of his employer.
management facility. In August 1990, the panel appointed the independent Scientific Review Group (SRG), a group of distinguished experts to conduct a specific in-depth examination of the scientific and engineering aspects of the disposal concept. The SRG is to report its findings on the acceptability and applicability of the scientific and engineering aspects of the concept to the panel.

BACKGROUND

The Canadian Nuclear Fuel Waste Management Program

Early in the nuclear energy program, it was recognized that some form of permanent disposal of high level radioactive waste would be necessary. In 1952, AECL was created under the provisions of the Atomic Energy Control Act to undertake research in the use of nuclear energy including the development of safe methods for managing nuclear wastes. Initial work undertaken in the development of these methods include the pioneering work on the immobilization of some fission products in glass, conducted by AECL scientists at the Chalk River Nuclear Laboratories, Chalk River, Ontario. At the same time and importantly, it was realised that long-term management of the nuclear fuel waste was an issue of high public interest.

During the early years of nuclear power generation in Canada, techniques for handling and storing radioactive wastes at power station sites were developed sufficiently to assure that these wastes could be stored safely on site in water-filled bays or concrete bunkers.

The anticipated importance of nuclear power electrical generation as a contribution to Canada's future energy supply and the increasing public concern regarding the overall safety of nuclear power indicated that it was essential for the government of Canada to formulate policies for the long-range management of nuclear fuel waste.

In 1973, the Geological Survey of Canada of EMR was asked by AECL to investigate the current status of nuclear waste disposal technology in geologic formations, and to recommend which formations might be suitable for Canada. It was determined that either hard rock or salt formations might be suitable, and that some hard rock formations, notably plutons, within the Canadian Precambrian Shield might be most appropriate. It was also recommended that research be conducted to identify suitable salt formations in Canada. Subsequently, EMR recommended that geoscience investigations focus on plutonic rock found in the Precambrian Shield of Ontario.

As a result of these and subsequent investigations, disposal of high level radioactive wastes in an engineered facility within a
pluton of the Canadian Shield was chosen as the primary option of a demonstration program. The demonstration program encompassed the verification of the basic concepts of geologic disposal, the recommendation of technically suitable sites for selection by government, and the construction and operation of a demonstration disposal facility. Complete information about the program, including details of economic benefits, health and safety considerations and environmental effects would be sent to local communities associated with the potential sites identified. In making a choice of location of such a facility, the wishes of the local communities expressed through their local, provincial and federal representatives would be closely followed.

During confirmation of a site's technical suitability, all relevant data will be presented in the appropriate form to meet the specific requirements of licence applications for the federal and provincial authorities concerned. Processes of decisions by governments, technical confirmation, local acceptance and licensing procedures through the regulatory authorities would result in the adoption of a specific site for the demonstration facility.

In 1977, EMR commissioned a study to review and make recommendations concerning the management of Canada's nuclear wastes (1). The study was done by an independent expert group chaired by Dr. Kenneth Hare of the University of Toronto's Institute of Environmental Studies. The main task of this study group was to review the quantity of radioactive material now in existence and likely to be produced in future years, and to reach conclusions as to how its ultimate disposal could be safety managed. The report of this group was to contain information of a quality and scope sufficient to serve as a general document for wide distribution both within government and to the public, in order to facilitate a better understanding of the waste disposal problem.

The study found existing Canadian policies that governed the handling of nuclear fuel waste had been established largely through the cooperative action of AECL and Ontario Hydro, with the concurrence of the appropriate ministers. These policies, and the programs based on them, had come into being with little public visibility. The authors recommended a much more open approach towards public discussion of nuclear energy policies was required, and that mechanisms be established for an effective interchange of information and ideas among the public, industry and government.

In endorsing the concept of geologic disposal, particularly within plutonic rock, the Hare report recommended that Canada urgently adopt a national plan for the management and disposal of nuclear waste. Such a plan should not only cover irradiated fuel and reactor waste but all aspects of the nuclear fuel cycle,
including mining, refining, fuel fabrication and the operation of nuclear power generating stations.

The Hare Report also suggested that members of the public, citizens’ groups, and agencies concerned with nuclear, health and environmental issues have the opportunity to comment on and criticize the provisions of this plan, and that the plan have broad public support before implementation.

On June 5, 1978, the federal Minister of EMR and the Ontario Energy Minister announced a joint program in which the federal and Ontario governments would work together on the first phase of a long-term program to assure the safe and permanent disposal of nuclear fuel waste. This program was thought to be a step toward a national plan to deal with nuclear wastes as recommended in the Hare Report.

The federal and Ontario governments agreed that AECL would be responsible for research and development relating to immobilization and permanent disposal of nuclear fuel waste. Ontario Hydro, a provincial utility, was to be responsible for the interim storage of this waste, and final transportation to any permanent disposal facility.

A further agreement on a program leading to the selection and acquisition of a site and the subsequent demonstration of geological waste disposal facility, would be concluded between the two governments as quickly as possible.

In April 1981, the Canadian government approved a ten-year generic research and development program in nuclear fuel waste management. The objectives of this program were:

1. to develop and demonstrate the technology for the storage, transportation, immobilization and disposal of nuclear fuel waste;
2. to develop and demonstrate the methodology and technology to characterize and select disposal sites;
3. to assess the environmental and safety aspects of the disposal concept;
4. to develop the basis for securing acceptance of the disposal concept through scientific and regulatory review and public information, interaction and participation.

In August 1981, the Minister of EMR and the Ontario Minister of Energy issued a joint statement which set out the process by which the disposal concept would be evaluated. The process would involve:
1. a regulatory and environmental review;
2. a full-public hearing;
3. a decision by the governments involved on the acceptability of the concept based on information and recommendations coming from 1. and 2.

Following the public hearing, the governments involved will have three options:

1. Concept acceptance. Confirmation by the Governments of Canada and Ontario would then be a prerequisite to selection of any site for a waste disposal facility.
2. Conditional concept acceptance. This would require further research work by AECL and resubmission of a final concept acceptance document.
3. Concept rejection. In this event, the governments of Canada and Ontario must consider alternative proposals.

It was agreed then that no site selection process for a permanent disposal facility would be started until the concept had been accepted as safe, secure and desirable by both governments.

The August 1981 joint announcement marked a major change in the Canadian program for the management of nuclear fuel waste. It was determined that the acceptability of the "concept" of geologic disposal of nuclear fuel waste would proceed and not accompany the selection of an actual disposal site. The Canadian program for geologic disposal investigation became generic in nature, a feature quite unique in comparison to other national waste management programs.

The federal government decided that the Atomic Energy Control Board (AECB), Canada's nuclear regulatory agency, would be the lead agency for both the regulatory and the environmental review of the disposal concept. AECB would be assisted in the development of standards, requirements and other regulatory functions by the federal Department of the Environment and the Ontario Ministry of the Environment. These agencies would adopt a consultative and iterative approach with all interested parties including public interest groups and the public in general.

However, it was recognized that AECB could be considered in a conflict of interest position if it were to appoint itself or appoint a panel to hold these hearings. This conflict of interest would arise because AECB documents on regulatory review and assessment of the concept, intended to provide a basis for decisions on the acceptability of the concept, would be subjected
to public review. In addition, AECB lacked a specific mandate and precedents for public hearings.

After many discussions on the part of the lead agencies, it was decided that the environmental assessment of AECL's disposal concept would be provided through the EARP.

Environmental Impact Assessment

Environmental impact assessment (EIA) has become an important tool for insuring that economic development activities can occur in an ecologically and socially sound manner. It is a mechanism that permits the integration of environmental and economic considerations in decision making and it has become a major component of project planning and resource management in Canada. EIA is designed to identify, predict, interpret and communicate information about the impact of a project on human health and well-being, including the well-being of ecosystems. The concern about the deterioration of the environment and the insufficient consideration given by government and industry to environmental impacts when considering options for development sprang not from government or industry but from the public.

This concern has forced a rapid development of the procedures in processes by which governments review and assess environmental impacts of projects or developments.

The Environmental Assessment and Review Process. The federal department of the Environment, as early as 1972, held discussions within which the federal government explored the possibilities for an environmental impact assessment process. In 1973, the Minister of Environment was directed by the federal Cabinet to establish, in cooperation with other federal Ministers, the Environmental Assessment and Review Process (EARP) for the environmental impact assessment of federal projects. In 1977, the EARP was adjusted by a second Cabinet decision to make provision for the inclusion within environmental assessment panels of individuals from outside the federal public services, to strengthen the requirements for early distribution of information to the public, and to ensure assessment for potential adverse effects on the quality of the environment early in the planning process.

The process was strengthened and updated in 1984 with the issuance of the Environmental Assessment and Review Process Guidelines (2) by an Order in Council, an administrative order made by the Cabinet under the authority of the Government Organization Act, 1979. This Guidelines Order is now the authority for the process. It reaffirms those aspects of the original policy and procedures that proved their worth and incorporates others that came about through evolution. Roles and responsibilities are more precisely defined and public
participation is reconfirmed as an essential element of the process from beginning to end.

EARP is a process that applies to all federal government departments, for projects they plan and implement directly and those where their approval in substantial financial assistance is required. The process was to help ensure that environmental matters are given appropriate weight in planning along with economic and technical factors. Therefore, the EARP is considered a planning, rather than a regulatory, process, intended to help administrators make good decisions, and to ensure that Canada's resources are not inadvertently wasted or irretrievably lost through lack of awareness or poor planning.

The EARP deals with the environmental, physical and biological, aspects of development proposals. However, the scope of a public review may be extended by the ministers concerned to cover the broader socio-economic effects, assessment of technology, the need for the proposal, or other relevant issues.

**Panel Reviews.** When an initial assessment leads to the decision that a proposal's potentially adverse environmental and directly related social effects are significant, or that public concern is such that a public review is desirable, the minister of the initiating department refers the proposal to the Minister of the Environment for a public review by an environmental assessment panel.

Each panel has a specific mandate, describing the nature and scope of the review, which is set out in the terms of reference issued by the Minister of the Environment.

Panel members are appointed by the Minister of the Environment for the duration of the panel review. Anyone can be chosen, provided certain requirements for objectivity and competence are met. Specifically, members must be free of potential conflict of interest or political influence, have special knowledge or relevant experience related to the proposal, understand and respect the purpose of the review process, and be independent of the federal government, the proponent and special interest groups.

**The Environmental Impact Statement.** All essential elements of a proposal are contained in one document, usually an environmental impact statement (EIS), which provides the focus of the public review. This document generally contains the following information: a description of the proposal, a discussion of the need for the proposal, a discussion of alternatives, a description of the present environment, resource use, and social patterns, a prediction of potential impacts, and an indication of how the adverse impacts will be mitigated or avoided.
The EIS is submitted to the panel and made public. Indeed, all material submitted to a panel during this, or any other stage of the review, becomes public information. The panel also allows sufficient time for review participants to examine and comment on the information received before it holds public hearings.

If the information in an EIS is adequate, a panel goes ahead with its public hearings. If it is considered deficient, the panel requests more information and the hearings are delayed until the material is received and reviewed.

**The Public Hearings.** Public hearings, held by panels, fall into two categories:

1. special meetings that seek public input on issues requiring further study during the review;

2. final hearings that provide the principal forum for public comment on the proposal and assist the panel in the eventual preparation of its report.

The hearings offer a public forum for supporting and opposing views of the proposal. To encourage the broadest public participation, hearings are as informal and flexible as practicable and are held in areas that could be potentially affected by the proposed project. No one can be subpoenaed to appear before the panel or asked to take an oath. There is no cross-examination in the legal sense and no need to be accompanied by legal counsel. However, the panel may question the relevancy and content of any information submitted to it.

Participation in the hearings by both the experts and the public, particularly those who live near the site of the development, is vital to the review. Although an impact may not be significant to experts, it may be for people living and working near the site. Local residents may have information and insights not available to an outsider.

**The Panel Report.** When the public hearings are completed, the panel writes a report for the Minister of the Environment and the minister of the initiating department. Panel reports usually contain a brief description of the proposal, the characteristics of the proposed site, the potential impacts, comments, issues and analysis, and conclusions and recommendation. It is the responsibility of the two federal ministers receiving the report to make it public.

The initiating department decides to what extent panel recommendations must be adopted before the proposal can proceed. The recommendations are incorporated into the design, construction, and operation of the proposal. The initiating department must see to it that decisions on suitable
implementation, mitigation measures, inspection, and monitoring programs are carried out.

Decisions stemming from the panel's recommendations are made public.

Evolution of the EARP

Over the more than fifteen years that environmental assessments through public reviews have taken place at federal levels, many significant developments have occurred that have changed and enhanced the assessment process. The following list highlights some of the more significant developments:

- the concern of the public as a whole, particularly those close to a site, will not be restricted to the physical environment; Socio-economic issues are perceived as important and inseparable from issues related to the physical environment. This close relationship is particularly evident in northern projects where the livelihood of people is more dependent on the natural environment. The public generally adopts a broader definition of the environment or potential impacts than stated in panel mandates or terms of reference.
- public participation has played an important role in determining the environmental significance of a development, and has often resulted in substantial changes to the original development;
- credibility in the eyes of the public is essential for a successful assessment process;
- proponents and government agencies have learned a lot about the value of public participation in decision-making, particularly in the direction subsequent efforts should be concentrated and in coordinating government policies related to a development; The public review of development proposals has resulted in greater accountability on the part of government agencies and proponents, increased communication between these agencies, and more effective mechanisms for presenting proposals.
- it has become incumbent upon the proponent to publicly demonstrate the need for a development, and to provide opportunities to involve and inform the public; The lack of effective information programs created public suspicion and resulted in a general misunderstanding of the nature of the project;
- there is often a demand for co-ordinated follow-up studies involving the public, the proponent and all levels of government to assess the impacts and recommend any additional mitigative measures;
intervenor funding for the public and public interest groups has been made available.

BRIEF DESCRIPTION OF DISPOSAL CONCEPT

The concept proposed by AECL is to dispose of nuclear fuel waste in an excavated vault deep in plutonic rock in the Canadian Shield. Nuclear fuel waste refers to irradiated fuel bundles discharged from reactors and high-level radioactive waste that would result from reprocessing of used fuel should the recycling option be adopted in the future.

High-level nuclear fuel waste in Canada are predominantly produced by CANDU reaction operations and are contained in irradiated fuel bundles. The used fuel discharged from the reactors is presently stored in water-filled bays at reactor sites.

AECL has been pursuing a research program on the immobilization and disposal of nuclear fuel waste, to establish the scientific basis for the assessment of the disposal concept, and to establish technical siting and design criteria for the future disposal vault. This program integrates research from the many scientific disciplines needed to assess the concept of permanent disposal, including studies in fuel immobilization, applied and fundamental chemistry and geochemistry, environmental research, environmental safety assessment and geotechnical evaluation.

The concept of geologic disposal consists of a system of multiple barriers, both engineered and natural, designed to prevent or retard the migration of radionuclides to the surface environment in amounts that would present unacceptable risks to man and the environment. These barriers consist of the disposal vault, the geosphere or enclosing plutonic rock, and the surface environment itself.

The disposal vault would consist of an engineered excavation 500 to 100 metres below surface in plutonic rock. The nuclear fuel waste would be sealed in containers and emplaced in the floors of rooms excavated in the rock mass. When the containers are in place and surrounded by buffer material composed of a clay/sand mixture the rooms, access tunnels and shaft would be backfilled with a mixture of clay and crushed granite and sealed to ensure that no pathway from the vault to the surface environment remains.

Ontario Hydro, over the same time period, has been responsible for research on interim storage and the final transportation to a disposal site.
PUBLIC REVIEW OF THE DISPOSAL CONCEPT

Scope of the Review

The review panel members are knowledgeable about issues likely to be raised in the review. Their expertise encompass a broad range of disciplines including geology, biology, engineering, health, and environmental, ethical, social and aboriginal issues.

The panel will review the safety and environmental impacts of the concept of geologic disposal of nuclear fuel waste along with a broad range of nuclear fuel waste management issues including:

- appropriate criteria by which the safety and acceptability of a concept for a long-term waste management should be evaluated;

- approaches to long-term management of nuclear fuel waste, including long-term storage with a capability for continuing human intervention in the form of monitoring, retrieval, and remedial action, and the transition from storage to permanent disposal;

- the degree to which future generations should be relieved of the burden of looking after the nuclear fuel waste;

- the use of different geological media and the experience of other countries in addressing their own nuclear fuel waste management issues;

- the social, economic and environmental implications of the nuclear fuel waste management facility;

- a recommended process and criteria for siting an eventual long term nuclear fuel waste management facility;

- the potential availability of sites in Canada and the methodology required to characterize them;

- general criteria for the management of nuclear fuel waste, as compared to those for the waste from other energy and industrial sources;

- the impact of recycling or other processes on the volume of waste;

- the next steps to be taken with respect to the management of nuclear fuel waste in Canada.

Since site selection will not take place until a disposal concept has been accepted as safe and acceptable, no specific potential sites will be considered.
In establishing terms of reference for panel reviews, it is customary to indicate the policy framework within which the panel is expected to conduct its review and those issues that the panel should not address. These include: the energy policies of Canada and the provinces, the role of nuclear energy within these policies, including the construction, operation and safety of new or existing nuclear power plants, fuel reprocessing as an energy policy, and military applications of nuclear technology.

Given the complexity of the issues associated with this review, a Scientific Review Group (SRG) of eminent, independent experts was appointed and given terms of reference by the panel. The SRG consists of scientists and engineers recognized for their specialized expertise in subject areas relevant to the disposal concept. These subjects areas include geology, hydrogeology, geophysics and seismicity, geochemistry, chemistry, biology, microbiology, civil, mechanical and mining engineering, geosphere modelling, and risk assessment. Each individual is expected to serve in his or her own capacity and not as a representative of any organization. The SRG will conduct specific, thorough and critical examinations of the safety and acceptability of the disposal concept and provide advice to the panel on other issues when requested. The SRG will report its findings to the panel for consideration and input to the public review.

The Review Procedures

The Panel will receive the EIS submitted by AECL and will distribute it to review participants for comment. If the Panel decides that the EIS is incomplete or inadequate, it will ask for additional information before scheduling public hearings. Once the Panel is satisfied that the EIS has adequately addressed the issues identified in the guidelines, it will announce public hearings. Review participants will have the opportunity to present their views on the AECL concept at the public hearings.

The Panel will consider all of the submissions received during public hearings and will present its conclusions and recommendations in its report to the Ministers of Environment and of Energy, Mines and Resources. The Minister of Energy, Mines and Resources, after discussion with the Minister of Environment, will decide whether the concept proposed by AECL is safe and acceptable, and what further steps must be taken to assure the safe and acceptable management of nuclear fuel waste in Canada.

The procedural steps in the review process are outlined in Figures I and II. Once the panel was formed one of its first tasks was the development of specific guidelines for the preparation of the EIS. To assist in the development of the guidelines, the panel held a series of general public meetings known as scoping meetings. Participants at these meetings included the general public, and organized groups including government agencies, environmental interest groups and the SRG.
The panel released a draft version of its guidelines in June, 1991 and invited written comments by the review participants. After reviewing comments received from the participants, the panel finalized the guidelines and released the document to AECL in March, 1992.

AECL, in response to the guidelines, will complete and submit the EIS to the panel, who will in turn distribute the document to the review participants and the SRG for evaluation and comment. The SRG will submit its review of the EIS to the panel for input into the public review process.

The panel will assess the adequacy of the EIS on the basis of its own review, the results of the SRG, and the reviews submitted by public participants, government agencies and other interest groups. If the panel finds that the EIS has adequately responded to its guidelines, it will then proceed to the public hearings stage of the review. However, if the panel feels that some issues have not been addressed adequately, it may require AECL to supply additional information or explanation prior to the convening of the public hearings.

When the panel considers that the information received adequately addresses the guidelines, public hearing dates and locations will be announced. The hearings offer a public forum to discuss issues of concern and to allow for supporting and opposing views on the proposal to be aired. To encourage the broadest public participation, hearings are held in locations and at times that are as convenient as possible for participants. The hearings are structures and follow pre-announced procedures but are quasi-judicial in nature.

Following the public hearings, the panel will review all the information received and will prepare its report for the Ministers of Environment and EMR. The report will contain a history of events associated with the concept of nuclear fuel waste disposal, an examination of environmental, safety, health and socio-economic implications of the concept, and the panel's conclusions and recommendations.

The panel's report will address whether AECL's concept for the geologic disposal of nuclear fuel waste is safe and acceptable or should be modified. It will also indicate the future steps that should be taken in the management of nuclear fuel waste in Canada.

The panel's report is advisory to Ministers and will be made public. The Governments of Canada and Ontario will decide whether or not to accept the panel's recommendations.
Present Status of the Review

The panel's guidelines for the preparation of the EIS were issued to AECL on March, 1992. These guidelines identify issues which the Panel has determined should be addressed in the EIS.

AECL is asked to present and describe a long-term comprehensive and adaptive strategy for the evaluation of possible impacts from concept implementation and from the contents of a disposal vault. AECL should outline plans for how this strategy will:

- establish what is currently known about possible impacts;
- acquire and incorporate new knowledge or information;
- allow for changes in design and implementation of the concept;
- adjust equitably to changes in social values and priorities;
- determine the conditions that would signal the attainment of various acceptable and unacceptable social and economic outcomes;
- reduce or eliminate adverse impacts.

The request for such a strategy is in response to the fact that many impacts may presently be largely unknown or incompletely defined. This is especially the case for this review given its conceptual nature and the absence of a specific site. Therefore, it is considered important to recognize the limitations and the boundaries of present knowledge as it applies to social, economic, scientific and technical considerations of the disposal concept.

The public and other participants in this review have approached the issue of nuclear fuel waste management with different views about the appropriate way to proceed, based largely on differences in ethical and moral perspectives. The panel feels that these ethical and moral perspectives, along with various social issues are as important as scientific, technical and economic considerations to assure the safe and acceptable management of nuclear fuel waste. Therefore, AECL has been asked to include in this strategy an investigation of how relatively narrow and focused considerations of a scientific, technical or economic nature should be viewed in the much broader context of ethical, moral and social considerations.

AECL has been asked to address the items and requests identified in these guidelines, and to include any information in the EIS that may contribute to a fuller understanding of part or all of the concept. The EIS should identify not only aspects of the
concept that are well understood, but also aspects for which at present only a limited understanding exists.

The following is a brief summary of issues raised by the panel in its guidelines:

**Nuclear Fuel Waste.** AECL is asked to define and explain the overall problem posed by nuclear fuel waste in Canada, and discuss the present magnitude and expected growth of this problem including:

- the origin and nature of nuclear fuel waste;
- current methods of nuclear fuel waste management in Canada;
- the ethical and moral framework in which the problem should be evaluated;
- the need for long-term management of nuclear fuel waste;
- the risks to the health of humans and to the natural environment.

**The Disposal Concept.** AECL is asked to describe the disposal concept, and present analyses and assessments of performance of the concept. The panel feels that this description should be presented clearly due to the complexity of the technology involved, the lack of experience in concept implementation, and the conceptual nature of information concerning a potential site. The panel has asked that the following issues be addressed:

- the assumptions and rationale underlying all decisions that will assist in the understanding and evaluation of the concept;
- regulatory criteria, their adequacy and their feasibility of being met;
- identification of what is uncertain or unknown, and how these uncertainties are treated;
- identification of gaps in significant knowledge;
- possible areas where future research results could cause a re-evaluation of the concept;
- the ranking of various phenomena and processes which may affect the performance of a future disposal facility;
- the use and justification of site-specific data, and its representativeness of human communities and of the natural environment in candidate site environments;
the flexibility of the concept or key components of the concept to accommodate possible unanticipated circumstances.

**Alternatives to the Disposal Concept.** AECL is asked to investigate possible alternatives to the disposal concept, and to describe each alternative, where possible, at a level of detail sufficient to permit a meaningful comparison with the concept.

**The Multiple Barrier System.** AECL is asked to explain the objectives, principles and assumptions involved in the development of the Multiple Barrier System to isolate nuclear fuel waste, and to describe each component of the Multiple Barrier System in physical, chemical and biological terms, its specific functions and, in particular, the linkages among the various components. Also important is to describe and quantify possible malfunctions of the barriers, or potential changes in the disposal vault environment that could affect the overall performance of the Multiple Barrier System.

**Performance Assessment of the Multiple Barrier System.** The EIS should discuss in detail and justify the procedures and approaches used to predict the long-term performance of the proposed Multiple Barrier System, including the extent to which these procedures and approaches are flexible enough to accommodate future development and refinements.

**Concept Implementation.** In addition to developing an acceptable concept for the long-term management of nuclear fuel waste, AECL should discuss the strategy and methodology for the implementation of the concept including:

- methods to characterize a generic site, and a discussion of the site selection process;
- a description of the disposal facility, and the transportation system;
- measures for environmental and occupational protection, and for emergency planning;
- approaches for the monitoring of performance and of possible impacts.

As well, AECL should investigate ways of involving the public in activities associated with concept implementation.

The panel has asked AECL to make use of appropriate case studies of the implementation of major projects in Canada that may assist in the understanding of the concept implementation, in particular, an understanding of the social and economic aspects of such implementation.
Impacts. The potential social, economic and environmental impacts of all phases of the implementation of a disposal facility and of the contents of a disposal vault on humans, human communities, the work site and the natural environment should be described and discussed in detail. AECL has been asked to consider the different viewpoints on the forms and significance of possible impacts, particularly the viewpoints of residents of northern communities, aboriginal peoples, people living near possible transport corridors and other public groups that have a significant potential of being impacted.

In order to achieve a clearer understanding of the concept, in particular the socio-economic aspects, the proponent is encouraged to make use of appropriate analogs, natural and otherwise, appropriate case studies of actual projects, and scenario analyses.

CHALLENGES OF THE REVIEW OF THE DISPOSAL CONCEPT

The environmental assessment review of the disposal concept offers unique challenges to all participants, non so greater than the fact that it will provide an essential foundation for future decisions on Canada's energy policy.

Some of these challenges include:

- the complexity and breadth of disciplines covered by the review; Information about the disposal concept supplied by many disciplines must be distilled in a manner so as to assist the panel in formulating its recommendations. Related to this challenge is the immense volume of material that has accumulated over many years of investigation.

- the conceptual nature of the review. Participants have been asked by government to conduct an environmental assessment of a concept, with no associated specific site. This approach is quite unique in environmental assessment.

- the long-term nature of the disposal concept. Many issues related to this disposal concept will not be resolved in our lifetimes. Setting in motion a strategy to resolve future problems and challenges associated with long-term nuclear fuel waste management and to assist future decision makers, requires unprecedented long-term multi-generational thinking.

- the focus on the decision maker. All participants in this review, particularly the panel, have the responsibility to provide the decision maker or our elected representatives with the best recommendations and information within the proper context so that the most a appropriate decision is made.
changing perspectives in society. A strategy to review long-term management of nuclear fuel waste must be flexible to accommodate changing perspectives, many of them short-term, and to meet the challenges of the participation of the public.

CONCLUSIONS

The environmental assessment review of the concept of geologic disposal of nuclear fuel waste is the likely the most challenging public review Canadians have faced to date. The Environmental Assessment and Review Process provides the vehicle to bring all the facts and viewpoints on long-term management of nuclear fuel waste into a single context, so that a group of independent citizens, the panel, can make recommendations to our elected representatives reflecting public opinion. This process attempts to ensure that sound thinking and good ideas are not isolated from the review, and conversely, that vested interests and narrow perspectives do not dominate. The success of the process to provide appropriate recommendations depends on the co-operation of all participants.

REFERENCES


FUTURE CONSIDERATIONS FOR STORAGE OF CANDU FUEL

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FOR PRESENTATION TO THE CNA/CNS CONFERENCE,
SAINT JOHN, N.B., CANADA, JUNE 7-10, 1992

ABSTRACT

The Canadian approach to permanent disposal of used CANDU fuel is directed toward its storage in suitable containers emplaced into an underground, stable, plutonic rock formation.

Permanent disposal of used fuel in Canada is expected to commence about 2025. At that time there will be sufficient quantity of used CANDU fuel such that the Used-Fuel Disposal Centre (UFDC) can be operated economically at full capacity. In the meantime, used fuel is stored on an interim basis at the reactor sites. The concept for permanent disposal is under review by a Federal panel. Upon approval of the disposal concept, site selection, design, and construction for the facility follows.

Initially, CANDU fuel is stored in water-filled bays at each nuclear station. Subsequently, five years after discharge from reactor, the fuel can be stored dry in concrete canisters. This option has been implemented at several CANDU reactor sites.

A coordinated program for handling used fuel on an interim basis and entailing all CANDU reactors in Canada, that will minimize handling of used fuel, is envisioned to achieve overall efficiency, cost reduction and to achieve compatibility with the permanent disposal facility. Accordingly, a standard receptacle for used CANDU fuel that would be suitable for interim storage, transportation and permanent disposal is desirable.

INTRODUCTION

Used fuel receptacles of various sizes and shapes are presently in use at different CANDU stations (Figure 1). Trays are in use at Bruce and CANDU 6 stations but the designs differ. Rectangular baskets were originally used at Pickering. Subsequently, rectangular modules were introduced at Pickering and these have also been adopted for use at Darlington.

When the original fuel-storage bays became full, auxiliary bays were built at some stations. More recently, others have opted for interim dry storage in concrete canisters with the fuel contained in cylindrical baskets (Figure 2). Dry-storage concrete canister facilities have been implemented at several CANDU sites including Gentilly 1, Douglas Point, NPD, Point Lepreau, and Wolfsong 1. Transfer of used fuel from the different trays into the cylindrical baskets for dry storage was necessary. This paper deals with defining the requirements for an approach to achieve consistency of storage methods to avoid the need for such transfer and subsequent fuel handling.
BACKGROUND

In 1974, AECL Research's Whiteshell Laboratories embarked on a program to demonstrate the feasibility of dry concrete-canister storage of used CANDU fuel. Four demonstration concrete canisters were constructed at Whiteshell. Following successful demonstration, the canister design was licensed for dry storage of used fuel in Canada.

In 1984, the Gentilly 1 prototype CANDU-Boiling Light Water (BLW) reactor was partially decommissioned, and the complete inventory of used fuel was placed in dry storage in concrete canisters (Figure 3) in 1985, applying the concept developed at Whiteshell.

Subsequently, this concept was also adopted at the partially decommissioned Douglas Point and Nuclear Power Demonstration (NPD) nuclear power plants where used fuel has been placed in dry storage in concrete canisters.

In 1991, when the irradiated fuel storage bay at Point Lepreau neared its capacity, the AECL developed concrete dry storage concrete program was implemented at a cost competitive with wet storage bays. In 1992, this program was also extended to the Wolsong 1 CANDU 6 reactor in Korea. All current CANDU 6 reactors are single-unit stations with the used-fuel storage bay constructed adjacent to the reactor containment building.

The irradiated storage bays at the Bruce nuclear generating stations are centrally located with two reactor units on each side. The bays were sized for ten years capacity, and when they became full, auxiliary bays were constructed in separate buildings. The bays are interconnected by a water-filled tunnel for transfer of irradiated fuel. The fuel bundles are stored in rectangular trays.

At the Pickering nuclear generating station, the used-fuel storage bay also was located between two reactor units. Fuel bundles were originally stored in 32-bundle capacity rectangular baskets. Subsequently, 96-bundle rectangular modules were introduced to increase the storage density, thereby increasing the used-fuel capacity of the bay. When the bay became full, an auxiliary bay was built, interconnected to the original bay via a corridor where a specially designed transport vehicle is used to transfer fuel in a cask that is filled and emptied underwater in the bays.

At the Darlington nuclear generating station, the used-fuel storage bays are constructed at each end of the four units to allow expansion of additional bay capacity adjacent to the original bays. The 96-bundle modules developed for Pickering were adopted for Darlington to further increase the storage capacity.

In the current concept of the Canadian Nuclear Fuel Waste Management Program, a permanent disposal centre will not be in operation until about 2025. As wet-storage capacity limits are approached, the question that needs to be addressed at each station is whether additional auxiliary bays should be constructed or whether dry storage should be adopted to meet future requirements. As well, the approach taken at that time should be done in a consistent manner to achieve a standard approach, compatible to the greatest extent possible with current fuel handling designs and future, long-term handling and storage facilities. The first receptacle used for storage of used fuel is seen to be a key component in achieving this objective.
DISCUSSION OF OPERATIONS

For purposes of discussion, the operations associated with the CANDU 6 station, where dry storage of used fuel has been implemented, will be described.

Used-fuel bundles at CANDU 6 stations are stored in rectangular trays (Figure 4). For transfer into interim dry storage, the bundles are transferred into cylindrical baskets on a working platform constructed at one end of the bay. After the cover is placed over the filled basket, it is raised into a shielded work station (Figure 5) that is constructed at the edge of the bay above the working platform. After forced-air drying of the bundles, the cover is seal-welded to the basket by a remotely operated metal-inert-gas (MIG) process.

The filled basket is then placed in a transport cask that rests on top of the shielded work station and transported to the concrete dry-storage canisters located outdoors at the site.

For the Point Lepreau and Wolsong 1 stations, the 304L stainless steel basket is approximately 1050 mm in outside diameter and 550 mm in height and holds 60 fuel bundles.

Each concrete canister holds nine baskets or 540 fuel bundles. The canister is a cylindrical, reinforced concrete structure with an internal steel liner 9.5 mm thick. The canister is approximately 3 m in diameter and 6.2 m in height. This provides a combined shielding of 0.94 m of concrete and 9.5 mm of steel. When the canister is full, a carbon steel-lined plug is seal-welded to the internal liner and IAEA safeguard seals are applied.

It has been demonstrated that used CANDU fuel can be placed in dry storage five years after discharge from the reactor. During the life of the station, approximately 4500 used-fuel bundles will be placed into dry storage annually. The canisters will be built at a rate of 10 per year (about 9 per year are needed for 80% reactor capacity factor).

THE DISPOSAL CONCEPT

Permanent disposal of used CANDU fuel would commence about 2025 according to the current concept of the Canadian Nuclear Fuel Waste Management Program. Casks for transportation of the basket/container to the Used Fuel Disposal Centre will not be required to be licensed until then. These would be designed to meet the licensing requirements in effect at the time.

The concept is to dispose of used CANDU fuel in an underground vault at a depth of 500-1000 m (Figure 6) in granitic rock in the Canadian Shield. Isolation will be achieved by means of a series of natural and engineered barriers comprising:

a. The used fuel form.
b. The corrosion-resistant container.
c. Buffer material compacted around the container.
d. Backfill material compacted within the emplacement rooms.
e. Access drift, shaft, and borehole seals.
f. The granitic rock environment.
Granitic rock was chosen as the disposal medium because of its long-term stability, low hydraulic conductivity, and abundance in plutonic forms in the Canadian Shield. Within the underground vault, containers filled with used fuel will be emplaced in boreholes drilled into the floor of individual rooms (Figure 7). Buffer material, a mixture of sodium bentonite clay and silica sand, will be compacted around each container in individual boreholes. Backfill material, a mixture of glacial lake clay and crushed granite from the vault excavation, will be used to backfill the disposal rooms and the rest of the underground vault, including the shafts.

FUTURE CONSIDERATIONS

The AECL concept for the permanent disposal of used CANDU nuclear fuel includes the transportation of used fuel in casks that will be suitable for road, rail and barge transportation. At the Used-Fuel Disposal Centre, used fuel contained in cylindrical containers is emplaced in the boreholes.

The Used Fuel Disposal Centre study was carried out to demonstrate the disposal concept feasibility, therefore optimization was not within the study's scope. Hence, the geometric size of the container (Figure 8) could be altered within reasonable constraints in future to achieve the objectives herein without affecting the concept's basic feasibility.

The basic design requirements for a CANDU used-fuel basket can be stated as follows:

1. Used fuel shall be discharged directly into a suitable basket from the reactor fuel-transfer system without being placed into any intermediate receptacle.

2. Once used fuel is placed into the basket, additional handling of individual bundles shall not be necessary, so that the same basket will be suitable for interim storage, transportation and disposal.

3. The size and shape of the basket shall be compatible with economic and technical considerations concerning fabrication, interim storage, density, transportation cask and disposal container.

4. Heat dissipation from the used fuel within a fuel basket shall not cause excessive heating during interim wet and dry storage, transportation or permanent disposal.

5. The size and shape of the basket shall be such that seismic, transportation and other loading requirements will be met.

6. Container and basket materials shall be compatible with the environments of the short, medium (interim) and permanent emplacement facilities.

Interim dry storage requires that the fuel bundles be transferred into containers that are compatible with the cylindrical concrete canister. Preferably, the containers will also be suitable for future transportation and permanent disposal. It may be necessary to fill the voids in the container with particulate material so that it will be capable of withstanding external hydrostatic pressures that it may experience during underground disposal.

The CANDU 3 reactor, which is presently being designed, has introduced a cylindrical basket (Figure 9) as the receptacle for storage of used fuel in the storage bay (Figure 10). This cylindrical used-fuel basket could also be used for subsequent dry storage and permanent disposal. This approach could be used for future used-fuel receptacles to minimize handling of individual bundles, to reduce cost and the possibility of fuel-bundle damage.
Furthermore, eventual disposal of redundant used-fuel receptacles could also be eliminated, thus, saving decommissioning disposal costs.

For a (metallic) road transport cask, the cylindrical shape has economic advantages over the rectangular shape due to relative ease of fabrication, e.g. machining. Design and fabrication of the road casks would not be required until around the year 2025.

Commercial application of the concrete dry storage canisters is now well advanced. The concept can provide further cost reductions through integration of the individual canisters into a concrete vault-like structure called CANSTOR (Figures 11 and 12). AECL has developed and tested this module which can store used-fuel volumes equivalent to 22 concrete canisters. The same basket/containers that are used at Point Lepreau and Wolsong 1 are compatible with CANSTOR.

CANSTOR is a rectangular, air-cooled structure about 7 m wide, 22 m long, and 7 m in height that stores 200 60-bundle capacity fuel baskets. Full scale thermal testing of the CANSTOR module concept was carried out in 1990 at Whiteshell.

CONCLUSIONS

Upon discharge from the reactor, used fuel can be placed in a receptacle that will be suitable for initial wet storage as well as for all future stages including permanent disposal. This would limit handling of individual bundles in future, avoiding potential damage to the fuel and the cost of additional handling operations.

Consideration should be given towards a system that is associated with minimum redundancy upon completion of the interim storage period. That is, the need to dispose of empty used-fuel receptacles should be avoided.

For disposal of used fuel in boreholes in an underground vault in granitic rock, the cylindrical geometry of the container is considered to be the preferred shape that will also be compatible with dry-storage concrete canisters and transport casks.

Permanent disposal of used fuel is not expected to take place until 2025 and, because licensing requirements for transportation then are unknown at this time, transportation casks will be designed to meet the licensing requirements in effect at the time.
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FIGURE 1 FUEL STORAGE CONTAINERS
FIGURE 2 STORAGE BASKET

COVER SEAL WELDED TO CENTRE POST AND BASE AFTER FILLING, COVER INSTALLATION AND DRYING
FIGURE 3  INTERIM DRY STORAGE CONCRETE CANISTER
FIGURE 4  CANDU 6 FUEL STORAGE STACK WITH IAEA SAFEGUARDS CONTAINMENT
FIGURE 5 DRY STORAGE BASKET LOADING EQUIPMENT
FIGURE 6 UNDERGROUND VAULT
FIGURE 7  USED FUEL CONTAINER EMLACEMENT
FIGURE 8  REFERENCE DISPOSAL CONTAINER DESIGN
FIGURE 9  IRRADIATED FUEL BUNDLE STORAGE BASKET MODULES AND STACKING FRAME
FIGURE 10  IRRADIATED FUEL BUNDLE STORAGE BAY (PLAN)
FIGURE 11 PLAN VIEW OF CANSTOR MODULE
SESSION 4

PUBLIC INFORMATION ADVOCATES

SESSION CHAIRMAN

Françoise Guennette
AECL Corporate Office
PEOPLE POWER—THE PUBLIC'S RESPONSE TO CNA'S PRINT AND TV ADVERTISING

Francoise Guenette
Vice-President, Corporate Relations, AECL

You will have noticed by now that the theme of this conference is "Public Acceptance and the People's Power".

No one can deny the power of people, particularly when they form a critical mass. Who will forget the news footage of Germans, both Easterners and Westerners, dancing on top of the Berlin Wall, or the sight of mass demonstrations around the Soviet Union in the weeks and months leading up to the dissolution of that former super-power.

We're here this afternoon to discuss how those of us involved in public information for the nuclear industry can harness "People Power" for the benefit of Canadians.

All of us attending this conference know that nuclear power is an important part of the solution to this country's energy and environmental problems -- we even have some politicians convinced of that. But as everyone knows, politicians do not make a move unless it reflects the desires of the majority of their constituents.

So we must reach the people -- figure out what concerns them and then plug nuclear into those concerns.

Plugging into those concerns. Our panelists this afternoon will help us do just that. Seated XXX is Linda Dyer, president of Baseline Research in Fredericton. Linda will give us her thoughts on what has to be done to move the numbers, based on her research. A recent questionnaire that she circulated gives us some interesting insight, and Linda will discuss those findings this afternoon.

Next to XXXX is Reg Tweeddale, the former general manager of NB Power. Reg will look at the leverage of citizens' groups in his province and will describe the evolution, mandate and activities of his blue-chip V.I.P. advocacy network which grew out of the Premier's Round Table on Environment and Economy.

On my XX is David Bock, vice-president for AECL CANDU's Western Region. David will describe some of the innovative and unique social marketing, grassroots lobbying, sponsorship and community relations programs that are part of Saskatchewan's campaign for a CANDU.

On David's XXX is Egon Frech, AECL's manager of corporate communications in Ottawa. Egon will review the public acceptance of nuclear waste management.
Before I call on our panelists, however, I'd like to take a few minutes to sketch out where our industry stands in terms of public acceptance, based on the post-testing recently commissioned by the CNA.

Post-testing is advertising jargon, and it refers to the surveys carried out after ads have been shown for a while to determine how much -- if, in fact, at all -- they may have influenced public opinion. It's like peeking into the oven half-way through to see if the bread is rising.

You'll recall that the print and TV ads the CNA is now running -- and you'll see some of them in a few minutes -- are the result of some earlier research conducted by the association to identify its prime target audiences.

Let me re-cap who those audiences are and how they were identified, and for those of you who attended CNA's Winter Session on Public Acceptance, I promise to be brief, as this information was covered off in detail at that meeting.

Research in recent years has consistently shown that most Canadians lie somewhere between "hard-core anti-nukes" and "staunch pro-nukes". We wanted to find out how to reach this large, malleable middle-ground with messages that would influence their attitude toward nuclear energy and move them to the support category.

We presented this challenge to pollster Angus Reid. Tell us why Canadians support or oppose nuclear power, we asked. His firm came back to us with a form of public opinion data analysis called "psychographic segmentation" that really seemed to dig out the "whys" behind support and opposition.

Psychographic testing has allowed us to identify groups of Canadians -- or clusters -- that share the same views on many different facets of the nuclear power issue. We now know the fundamental beliefs of a cluster, as well as its size and demographic composition. This information has been priceless in planning our communications activities.

(SLIDE 1 -- Cluster slide) Here are the five clusters identified through our research. They range from Informed Advocates on the plus side to the Activist Opponents on the negative end of the scale, both of which comprise about 20 per cent of the population. Also on the plus side are the Pragmatic Supporters who are somewhat less enthusiastic about nuclear in principal, but who acknowledge it as a reasonable alternative.

The clusters in the middle -- the Cautious Traditionalists and the Receptive Conformists -- are perhaps the most interesting group, accounting together for 45 per cent of the population.
We call them the persuadables and our new strategy aims directly at them.

Reaching the persuadables is exactly what the advertising I'm about to show you is intended to do. This advertising, I might add, comes after numerous focus groups were conducted to be as sure as possible that our messages would be effective.

For the first time, we're taking our messages to media outlets in some of the small urban centres. We're not ignoring larger cities like Toronto, Montreal and Ottawa, but we're also paying attention to Windsor, Thunder Bay, Kitchener, Barrie, Trois Rivieres, Sherbooke, Regina and Saskatoon -- smaller cities heavily populated by persuadables.

Before I show you our television ads, let me give you a taste of what's been appearing in print, in English-language magazines such as Maclean's, Equinox, Canadian Geo, and Time et, en francais, dans Actualite et Affaires. (SLIDES 2-7, Recent flight of magazine ads ending on French Safety ad.)

In terms of television, we modified our media buy, branching out from public affairs programs, such as Canada AM and World Beat News, to mainstream TV such as sports (Blue Jays Baseball, Hockey Night in Canada), Wheel of Fortune, Golden Girls and the CTV Monday Movie. For the first time, we also started running our ads during the soaps and the day-time talk shows. If you tuned into Oprah or Another World, there was a good chance you saw one of these ads. If your interests lean toward the extra-terrestrial, you would have caught our advertising during Star Trek. Beam me up Scottie and let's screen the ads. (CUE TO RUN VIDEO OF ENGLISH ADS.)

Of course, we applied the same targeted approach to French-language TV.

Early results are now in on this strategy. From April 21 to April 28 this year, Angus Reid conducted a nation-wide telephone survey of approximately 1,500 randomly selected Canadian adults. The results were weighted to ensure that the sample's age/sex composition reflected that of the Canadian population. The findings are considered accurate 95 per cent of the time, within plus or minus 2.5 per cent.

Overall, the post-test results are encouraging and give us reason to believe our advertising is on the right track. Let me give you some of the highlights: * (SLIDE 8 -- Overall support for nuclear energy.)

There has been a marked increase -- up 11 per cent -- over the past year in support for the use of nuclear technology to generate electricity in Canada. We're now in the process of
validating the research. In our business, we're so used to getting bad news, we don't know whether to believe good news. But one way or another, support appears to have risen across the country.

* (SLIDE 9 -- Safety of Nuclear Technology.) There has been a 21 per cent jump in the number of Canadians who believe that nuclear technology as a means of producing electricity is safe for the environment.

Sixty-one (61) per cent now say "somewhat" or "very safe". This perception is strongest in Ontario (71 per cent), the Atlantic (66 per cent), and Manitoba/Saskatchewan (60 per cent).

* (SLIDE 10 -- Message recall for TV advertising) The safety messages in our advertising -- both pertaining to the environment and our nuclear power plants -- had strong pick-up.

By contrast, the nuclear medicine message was remembered by only 8 per cent of those who recalled a television advertisement. I must admit that I find this result somewhat puzzling, so we'll focus some of our efforts in the future on finding out why.

* (SLIDE 11 -- Overall advertising penetration) Of those surveyed, nearly two-in-five -- 36 per cent -- recalled seeing an ad about nuclear energy in Canada.

The highest levels were recorded in our key markets of Ontario and Quebec, and recall was disproportionately stronger among men, younger Canadians, and the better educated.

* The messages in both TV and magazines were seen as highly credible.

(SLIDE 12 -- Believability of TV messages) Of those who remembered seeing a TV ad on nuclear energy, a strong majority -- 72 per cent -- found the message to be at least "somewhat believable." What's really exciting is that nearly a quarter -- 22 per cent -- of those who recalled seeing a TV ad said the message was "very believable". By any standard, these are excellent credibility numbers.

* Perhaps the most interesting findings of the study suggest that not only are our messages on the mark, the advertising built around those messages is effective. (SLIDE 13 -- Impact of seeing ad on support) Two-in-five -- 37 per cent -- said seeing the ads increased their support for the use of nuclear energy in Canada.

I'm not going to stand here and claim that the ads alone were responsible for increasing the overall level of support some 11 percentage points. In fact, the public opinion data indicate that even among those who did not see the ads, support grew.
And there are a number of factors that may have contributed to this. It is possible that statistical margin of error and questionnaire influence could account for up to three to five per cent of the overall increased support. And we mustn't forget that the CNA continues to provide a full range of communications vehicles to keep the facts in the public eye. Nor can we discount the cumulative effect of years of proactive communications. But perhaps the greatest influence this time around is the effect of the spread of real public concern about the environment -- and the strong pick-up on the environmental messages in our advertising may be one indication of this.

(SLIDE 14: Support for Nuclear Power) Further analysis shows that the difference in support between those who did recall seeing the ads and those who said they did not see them was nine per cent. That's a real and significant difference which, once again, may reflect the timeliness of our environmental messages as well as the changes to our media buy.

No matter how you look at it, our ads are having a positive impact. We should feel good about this shift because it shows that our messages are on the mark and targeted at the right audiences. We should feel even better because many people are coming to the conclusion on their own -- even without our advertising -- that nuclear power is environmentally safe. Our ads appear to be reinforcing this trend and accelerating it. (SLIDE 15 -- Go to blank screen.)

But we mustn't get complacent. The post-testing also points out that there is a long road ahead of us. For example:

* The tracking results show that in some cases the yard sticks have not moved. The same proportion of Canadians as a year ago still believe that the nuclear industry is contributing to medical technology, that safety and containment systems at nuclear plants are suspect, and that the same number believe that the nuclear industry is incapable of managing its waste.

* What's more, if a majority of Canadians -- 53 per cent -- now say they favor the use of nuclear technology as one of the ways to generate electricity, that still leaves 47 per cent who do not or are ambivalent. You can see the magnitude of the task before us. As Margaret Thatcher once said, "You may have to fight a battle more than once to win it."

But there's no question that we are making in-roads -- and we have more than the post-test results as proof of that. The number of calls to the CNA 800 number -- which is listed at the bottom of all our print ads and appears on the final frame of all TV advertising -- is way up. So far this year, there have been 1,800 calls to the 1-800 line, compared with just 1,200 last year during the same time period. That's a 50 per cent jump in
activity. People are interested and they're using the telephone to prove it.

I've just given you some indication of public acceptance polling going on right now at the CNA. It's an on-going, evolutionary process that you'll be hearing more about and one that's committed to dialogue with our audiences. We're determined to listen, empathize and address what concerns all our target groups, particularly the persuadables.

That same approach is being reflected elsewhere across the country, as well, as you'll see from the presentations of our panelists. It's an indication of the determination in this industry to tap the power of the people that I referred to at the start of this session.

Now allow me to introduce our first panelist to speak this afternoon, Linda Dyer.

Linda is the president and research director of Baseline Market Research Inc., a company she founded in 1985 with offices in Fredericton, Halifax, Sudbury and Toronto.

She holds her MBA from the University of Maine and is a resident of this country by choice, having moved to this province in the early '80s to assume a position with the Faculty of Administration at the University of New Brunswick.

Linda is an expert on qualitative and quantitative research projects, and has personally conducted several hundred focus groups.

We're delighted to have her here today to share her recent research findings that show how knowledge of an audience enhances the communication of messages. Linda...

(LINDA DYER'S PRESENTATION)

Thank you Linda for some thought-provoking results. Next at the podium is Reg Tweeddale. Reg is a familiar face to many in the industry, particularly those of us who had dealings with NB Power from 1957 to 1968, when Reg was general manager.

His post-NB Power career has included a stint as director on the New Brunswick Forest Resources Study and work as a consultant for firms such as AECL -- and we appreciate very much the work you are doing Reg on our behalf in this province. Grassroots support for a second Point Lepreau is strengthening, particularly in light of the poll conducted for the Saint John Construction Council and announced earlier today. The poll results show that 61 per cent of 400 Saint John residents asked were in favor of building a second reactor at the Point Lepreau site.
Reg is doing other good work for New Brunswick as well. In 1988, Reg was appointed as a member of Premier Frank McKenna's Round Table on the Economy and the Environment, and it is his work in this area that will be the subject of his remarks today. It is a pleasure to introduce Reg Tweeddale...

(REG TWEEDDALE'S REMARKS)

Thank you Reg. Now we'll move west to Saskatchewan. David Bock is vice-president of AECL CANDU's Western Region Office. Before joining AECL, he was senior advisor to the deputy premier of Saskatchewan and prior to that he held senior positions with the Saskatchewan Liquor Board, the Saskatchewan Public Service Commission, and the Saskatchewan Department of Finance. Please welcome our man on the prairies, David Bock....

(DAVID BOCK'S PRESENTATION)

Thanks David for bringing us up-to-date on the grassroots work being done in Saskatchewan. Now for our final panelist, and then we'll open the floor for questions.

Egon Frech recently assumed the position of manager, corporate communications for AECL, but prior to that for 13 years he was located at our Whiteshell Laboratories in Manitoba heading up our waste management public affairs program. Egon is credited with developing the Canadian public acceptance strategy and public affairs program for nuclear fuel waste management.

A former journalist and special assistant to Ed Schreyer when he was premier of Manitoba, Egon is also a former champion auto rallyist and sailor and is an avid private pilot. It is a pleasure to turn the microphone over to Egon Frech.
MOVING THE NUCLEAR NUMBERS - WHAT IS REQUIRED?

L. Dyer
Baseline Research

This paper is not available.
Citizens' groups are the hallmark of free democratic societies. Characteristically, they support worthy causes or oppose what their members perceive to be abuses of power or anti-social actions. But whatever their objectives, they are almost invariably focused on some quite narrow target or ethic—even a single issue. We in New Brunswick have our fair share of such groups, but our experiences with them are in no way unique.

But one citizens' group with which I am presently involved came into being precisely because its members felt the need to aim at a very broad target, namely a well balanced overview of the problems confronting a greatly over-populated world striving to improve its living standards—while in doing so threatening its own environment, its own welfare, and arguably its own existence.

In 1987, under the United Nations, the World Commission on Environment and Development (the "Brundtland Commission") released its report titled "Our Common Future". It urged governments everywhere to take speedy and drastic actions to halt alarming deterioration of the world's physical environment. Concurrently with the Brundtland study, the Government of Canada had set up a National Task Force on Environment and Economy dealing with substantially the same issues. In 1987, this Task Force also published its report. The developments prompted the Federal Government to invite all the provinces to address their concern without delay.

In 1988, the Government of New Brunswick complied with this invitation by creating the Premier's Round Table on Environment and Economy consisting of five cabinet ministers and ten businessmen, academics and others drawn from the public-at-large, of which I was one. The mandate of the Round Table is to prepare a sustainable development strategy for the Province.

One of the early acts of the Round Table was to conduct a program of a dozen public hearings at various centres throughout the Province during the fall and early winter of 1989/90. At these, members of the public were invited to express their views.

The Round Table's next step was to establish 13 "Sectoral Groups" or committees whose duty it was to examine the environmental/economic problems within distinct segments of the provincial economy (e.g. agriculture, energy, education, ect.), and to suggest appropriate actions to reduce conflicts between economic growth and the welfare of the environment. The Sectoral Groups
consisted of representatives with relevant special interests. Many, but not all of them, had professional expertise in their fields.

In the fall of 1990, the Round Table published its "Draft Report" which was based on opinions expressed at public hearings, the recommendations of the Sectoral Groups and the views of its own members. In a second round of public hearings in the late spring and early summer of 1991, the Round Table sought public reaction to its Draft Report and its tentative conclusions. The Round Table's final report is now nearing completion.

Ideally in a process such as this, conflicting opinions should result in a reasonably balanced consensus. Sadly, this was often not the case. Loud and emotional voices prevailed (not infrequently using false or distorted information). In part, this resulted from the fact that business and professional organizations failed to take full advantage of their opportunities to present their views. The "Draft Report" of the Round Table reflected this imbalance with the environment receiving overwhelming attention at the expense of the economy which, after all, must support any improvement in the environment.

It was this very disturbing imbalance which prompted the formation of an ad hoc citizens' group in Fredericton, NB. Its aim was to examine the tentative conclusions of the Round Table as set out in its "Draft Report", especially in the way they related to reports of the Sectoral Groups which were also studied in detail. This citizens' group has no formal name, no constitution, no officers, no fees, no special interest, no recognizable political "colour", but it does have an exceptionally broad-based membership with expertise in many fields; not only in the "learned professions", but also in the more prosaic ones. It has taken a critical look at several sections of the Round Table's Draft Report. As an aside I might add that recently it has made an in-depth study of Canada's constitutional problems. On all these matters it has submitted briefs to the appropriate decision-makers.

I would like to talk about what this group has had to say on such subjects as transportation, fisheries, forestry, water education, and public information. But this Conference is about nuclear energy. In short, this group strongly favoured a shift away from fossil fuels in favour of nuclear power when New Brunswick will need to increase its output of electrical energy to accommodate increased demands. Its reasons for doing so I shall deal with later.

When the Round Table's Sectoral Group on "Energy" was set up, the powers-that-be were at pains to ensure both sides of the "nuclear option" were represented in its membership—and rightly so.
But this turned out to be a prescription to guarantee a deadlock on the issue. To a degree the Draft Report of the Round Table reflected that deadlock.

Here let me digress to talk briefly about the relationship between people and energy. Until the industrial revolution, mankind had depended almost exclusively upon muscle power of men and animals to drive its economy with only peripheral assistance from the elements—wind and water. Populations were held in check by pestilence, accidents, wars, natural disasters, starvation and physical exhaustion. Countering these pressures on population control was an almost universal and natural urge to create large families to supply more muscle power and to compensate for untimely deaths. Modern medical science, enormously greater efficiency in the production and transportation of food, and globally organized disaster-relief efforts have led to longer life expectancy throughout the world, including the "third world". And, it must be noted that none of these advances would have been possible had it not been for rapid advances made in the application of mechanically produced energy.

But the production of mechanical energy on a large scale has not yet reached the third world, and that is precisely why the third world is under-developed. So the desire for large families still exists while the pressures to limit populations have been relieved. The result is a population explosion in the energy-deficiency third world, while population growth is slowing in the western societies that are self-sufficient in energy. Overall, for every inhabitant of the world at the time of the industrial revolution there are now seven or eight—and the ratio is still climbing. This is a fundamental and unmanageable reality which must always be factored into solutions to environmental and economic problems that have global significance.

Surely the next major development will be the industrialization of under-developed countries and, it is hoped, an accompanying tendency to suppress large human population increases.

Now I return to the citizens' group I spoke of earlier. It has been described as being dominated by nuclear-energy professionals and enthusiasts. This is not so. It is true that the group includes several members who are directly or indirectly associated with the nuclear industry—all of them very knowledgeable in nuclear energy. But the majority of its members have quite different backgrounds. Many of them have come to favour nuclear energy as being clearly a lesser evil than any practical alternative. For them the threat of the "greenhouse effect" is far more plausible than the threat of nuclear disaster from peaceful uses and with far more serious consequences—even without taking into account the costs in lives and health attributable to the use of alternative fuels.
Their line of reasoning goes like this. There is a widespread and well-founded understanding that the combustion of fossil fuels (indeed any carbonaceous fuel) is the principal contributor of "greenhouse" gases and a major factor in the production of acid rain. Such combustion can also release significant amounts of radioactive and other harmful materials to the environment. For a variety of reasons, environmentalists are increasingly opposed to larger new hydro-electric developments. Solar energy and wind power have useful but very limited applications in most of Canada and in New Brunswick. Conservation of energy is highly desirable and should be promoted by all practicable means, but that is a "once only" option; all new installations will tend to embody maximum efficiency. However conservation cannot for long keep pace with new demands for energy—particularly electrical energy. On the other side of the same coin is the third world's clamour to enter the industrial age. The key to that entrance is mechanical energy.

It is almost certain that the choice of developing countries will most often be for energy produced from fossil fuels particularly coal. That will add greatly to the production of "greenhouse" gasses and its consequences. If that is so, industrialized countries should not only be turning to nuclear energy for additional needs, but should also be phasing out fossil-fuel energy as fast as practicable to minimize the adverse affects of increased use of fossil fuels in less-developed parts of the world. There should also be encouragement to those countries to choose the nuclear option initially. To meet the global energy needs of society in the future it is hoped that nuclear fusion will become the source of those needs. Yet in the time that it will take for this development, nuclear fission is the safest and most benign method of bridging the energy requirements of the future.

The CANDU nuclear system produces electrical energy not only in a safe and environmentally friendly manner, but its energy production is cost-competitive as well. With the higher capital costs being stable and amortized in the case of nuclear installation, and with the higher fuel costs of conventional plants being severely subject to uncertainties and inflation, the trend will be for energy costs from nuclear generation to become even more economical with time, unless the trend to over-regulation persists.

The controlled generation of nuclear energy is a safe high-technology undertaking. The Point LePreau generating station, here in New Brunswick, is one of the outstanding such plants in the world. It has a lifetime capacity factor of 91.1% (it first came in service in February 1983). In the last five years, it was ranked first once and second four times among all the nuclear power plants in the world larger than 150 MW. That proves that we have the level of expertise needed to be the best.
With the obvious need for additional electrical energy in the future, both locally and globally, together with the increasing concern for the environment as well as the growing international acceptance of the CANDU system, the potential market for 35 to 40 of the new CANDU3 reactors in the next 25 years is not unreasonable.

New Brunswick has successfully demonstrated the benefits and merits of the CANDU-6 size nuclear unit. With a similar demonstration of the more advanced and smaller CANDU-3 unit, it would be expected that a very considerable share of the commercial benefits in engineering, manufacturing, marketing, training, etc., as well as a share in future nuclear research should be centred in New Brunswick and the Atlantic Region. The building on past success and taking an active role in a large growing and needed high technology of this nature could be one of the few opportunities that New Brunswick has to help it to become economically self-sufficient and also to help address the concerns of environmental dangers.

New Brunswick is well located in relations to the heavily populated, highly industrialized northeastern United States and to neighbouring Canadian provinces. It is therefore well placed to coordinate and cooperate with those jurisdictions in planning contractual energy arrangements that maximize mutual benefits in the environment and the economy.

The citizens' group reinforced its views on its nuclear energy preference with a 17 page appendix refuting most of the objections raised against expanding this method of energy generation. (For those who may be interested I have a few copies of the Fredericton Citizens Group brief on the nuclear energy issue.)

In my opinion, the performance and output of this citizens' group present an excellent example of what a well informed, unbiased, and objective collection of individuals can accomplish when it conducts joint studies and analyses of possible, but often conflicting, options. It has no "axe to grind" other than to seek the best solution to problems of sustainable development in an over-crowded world placing enormous pressures on its finite resources and environment. I wish there were many, many more such inquisitive, open-minded, public-spirited groups in New Brunswick and all the provinces of Canada.
POPULARIZING THE PEOPLE'S POWER ON THE PRAIRIES

Presented to

THE 1992 CNA/CNS ANNUAL CONFERENCE

St. John, New Brunswick
June 7 - 10, 1992

by

David A. Bock
Vice President, Western Region
AECL
I had some jokes and funny stories but Francoise cut my time in half so I will have to stick to the task at hand.

My topic is popularizing the people’s power on the prairies. I am not quite sure what that means, but if it has to do with marketing nuclear, it all goes back to basics: knowing what your product is, defining who your customers are, and packaging and presenting your product as something they might consider buying.

The first step in marketing a nuclear reactor is to determine that there is a need for additional generating capacity within a reasonable time frame. It seems that in spite of all the sophisticated computer packages and tools available to the planners, forecasting future demand is even less predictable than it was in days gone by, especially after a change in government. It seems that energy conservation may have as much to do with voting patterns as it does to expensive light bulbs which is proof that Amory Lovins is on the wrong track.

After need is determined, the next task is identifying your customer which is not quite as simple as it sounds either. The utility people are fairly straightforward. They want reliable, economically priced electricity that fits into the grid, but a fundamental fact in our business is that utilities in this country tend to be Crown corporations. In dealing with the issue of a nuclear plant, especially the first unit, there is fear that the plant will generate as much controversy as electricity and, when you combine this with high capital requirements at a time when capital funds are scarce, some interesting challenges are created. In addition, mega-projects of every description are coming under increased scrutiny for environmental, political, or economic reasons. In the last few years, building of dams have run into serious problems in Saskatchewan, Alberta, and Quebec. Similarly, cost overruns have caused difficulties at Darlington as well as the bi-provincial heavy oil upgrader at Lloydminster.
That brings me to the public. In the case of Saskatchewan, the number one concern is the economy because economic activity is needed in order just to survive, let alone prosper. Many of us see the nuclear industry, including fuel cycle opportunities, as one of the more promising sectors to pursue.

In a general sense, our approach is community-based marketing where an awareness of the issue or product is created, a comfort level is achieved, and the audience becomes receptive to the message. This is not difficult in the nuclear industry because we have a good message: safe, clean, convenient electricity and a promising future globally. In Saskatchewan, there is also a dream... a better future for Saskatchewan people and their children. High quality and high paying jobs for our sons and daughters so they can raise their families and have a secure future in Saskatchewan rather than the current situation of having to leave to find work.

In the case of nuclear, people also want to know that the reactors are safe and that there is a solution to the problem of high level nuclear waste. The general public is influenced by stories of Chernobyl and Three Mile Island because the anti-nuclear groups, aided by the press, have been very effective at terrorizing the public over the years and it is only now that we are seeing any balance in the debate. Much of that can be attributed to the serious environmental problems associated with the combustion of fossil fuels, not to mention the danger of coal mining. Imagine the impact on our industry if there was even one fatality in a nuclear power plant. Yet, in the coal industry, they are wondering how soon they can start up the mine.

In dealing with the public as our primary customer, we first segment our market in different groups, recognizing that they have different interests and aspirations.

Our priority market segment is education and youth. We have, and will continue to view this as the core of our program. In dealing with the educational system, there has to be a longer-term view which meets the needs of the professional educators.
Our information program started some two years ago when we proceeded to develop an information centre to provide a focal point in working with the educational community and the public. We put a great deal of emphasis on taking our message out to the public with speaking engagements being one of our key activities.

In addition to a very active speaking program, we are in attendance at most teacher conventions, participate in organizing the teachers' summer resource tour and attend career days in the schools. We have an annual energy competition which started out as an essay contest and, this year, we increased the technology level by changing the venue to videos. We have participated in science fairs and we are involved in promoting science as a career through the Women's Network mentoring program. We also assisted the university in a very successful session of introducing grade 8 girls to engineering as a possible vocation.

AECL sponsored the first film at the new IMAX Theatre called, "The Dream is Alive" which is about man's ventures into space. This was even useful for our international program when KEPCO's President Ahn visited our province last year. We are also a supporter of a private educational group whose mandate is to educate young people about the relationship between man, minerals, and materials.

Our second priority has been municipal government which is the basis of grass roots politics. Local politicians (we had a good example this morning) are much closer to the public than more senior levels and, since there is no formal party system in municipal government, at least in Saskatchewan, there tends to be less posturing and more focus on real issues and solutions. Our efforts have been primarily directed at rural and urban municipalities. The most effective way of gaining support of these organizations is to concentrate on the executive and show them first hand the size, impact, and benefits that the nuclear industry has created in other areas. Working with the executive leads to many opportunities to speak at ratepayer and regular regional meetings.
The Saskatchewan Association of Rural Municipalities and the Saskatchewan Urban Municipalities Association have overwhelmingly endorsed the establishment of an expended nuclear industry in the province and there is no question that these two groups are very influential regardless of what party is in power at the provincial level.

Business and professional groups have a natural interest in an expended nuclear industry because it leads to increased economic opportunity. Efforts were made to ensure that the leadership of these organizations were well informed and, again, this resulted in numerous opportunities to address their members. To focus on their interests, AECL hired a national consulting firms to undertake a study of the financial, employment, and economic impacts of an expended nuclear industry which not only included the reactor technology side, but opportunities in the nuclear fuel cycle as well. Thousands of copies of this study were handed out to business groups and local government.

Saskatchewan also has a high native population and, in recent years, the various native groups have been actively seeking solutions to high unemployment and poverty. From the very beginning, we have made efforts to ensure that Indian chiefs and councillors be included in plant visits and that speakers were available to Indian and Metis assemblies and meetings. AECL sponsored a science camp for native children and we engaged an aboriginal communications firm to publish the "Saskatchewan Nuclear Gazette", a magazine addressing a broad spectrum of nuclear related topics. We also have proposals for joint studies which the native groups are pursuing with the provincial government.

The labour movement in Saskatchewan is considered an important basis of support. Most of the uranium mines are unionized and the employees of the utility, SaskPower, are represented by the IBEW and the Energy and Chemical Workers. the construction unions, who are affiliated with the Canadian Federation of Labour, are particularly interested in our message because they understand the size and complexity and how that translates into well paying, long term, union jobs. In addition, unions tend to have a close connection to the NDP which is important since the change in government.
Our sponsorship and special events activities range from small items such as irradiated golf balls and golf shirts for prizes for charity golf tournaments to being a major sponsor of the Canadian Special Olympics winter games and, for those of you who are not familiar with the Special Olympics program, it is simply amazing what people with handicaps can accomplish when they are provided with a little support. If the rest of us had the same attitude as these people, we would be leading the world in most every field.

We are currently working with our junior football team, The Saskatoon Hilltops, to send a young swimmer to Spain to compete on a world basis in the Special Olympics. This young man who lost a leg to cancer has an excellent change of winning a gold medal. I also have to run in the fact that our football team, the Saskatoon Hilltops, won the Canadian Junior Football League championship by defeating the Ottawa Sooners by a score of 55 to 7 which was very gratifying to our office and very disappointing to our corporate cousins in Ottawa who, incidentally, helped with the commemorative T-shirts.

We also were one of the sponsors of the Knights of Columbus indoor track meet which provided some useful contacts in the Catholic church. We have made a special effort to work with women’s groups and have provided sponsorships in precision skating, senior girls basketball, curling, and the Literacy Foundation. We have worked with Big Sisters and Girl Guides. We are the sponsor of the Wildlife Artists annual show and sale and have helped charities such as the Heart and Stroke Association, the Red Cross and the George Reed Foundation in raising funds.

Our parade float added some colour to local parades and we have a booth at most fairs and exhibitions. Our shopping mall program has been very effective in contributing to public awareness and the mall management and stores view us in a very positive light.
AECL has also worked with many groups concerned about the direction and need for growth in the Saskatchewan economy. One such group, Synergy Today, has become quite an effective lobby group, not specifically for CANDU or AECL, but for the need to rationally evaluate the province's economic development options. Another group, Students Advocating Nuclear Energy (SANE) has also increased awareness of the nuclear industry's potential in terms of creating high quality jobs for young people. We have also received a lot of support from Saskatchewan's business leaders and, in the uranium mining industry, CAMECO's President, Bernard Michel, deserves special mention.

The results?......Let me show you in headline form!

1. Signing of Nuclear Deal
2. NDP Election Victory
3. NDP Party Voting Against Agreement

In March, 1992, the newly elected government "opted out" of the SaskPower/AECL agreement, citing cost concerns and uncertainty in the demand for power. The real reason had to do with the internal party politics and the need for time to address these issues within their caucus and party structure. The Saskatchewan Energy Conservation and Development Institute will provide a mechanism to allow a rational assessment of the nuclear option within the Saskatchewan context.

4. Romanow Cancelling Agreement

Two months later, the Saskatchewan government announced its intention to continue discussions on a nuclear agenda with two specific requirements: 1. that the reference to waste storage be eliminated and, 2. that construction of a nuclear reactor would have to be endorsed by the Saskatchewan Energy Institute. Neither of these conditions are problematic to AECL, especially waste disposal since the concept is still under review. The Energy Institute means that there is yet another process that we have to accommodate but we are looking forward to working with this group once it is established.
In conclusion, it is difficult to empirically attribute cause and effect of our program, however, it is reasonable to conclude that the Saskatchewan public became more aware of the nuclear option and a significant portion of the population expressed this view to their government with sufficient clarity and forcefulness to encourage the new government to continue pursuing discussions on the nuclear option.

At any rate, suffice to say that there is strong support to include nuclear as part of the province's economic diversification strategy. Time will tell the extent to which this occurs and, in the final analysis, it will be up to the public and their elected representatives to decide and, in a democratic society, that is the way it should be. On the positive side, all past governments in Saskatchewan have supported the nuclear option while in power and I suspect that Mr. Romanow will do the same but it will have to be done in a way that allows him to deal with some of his internal difficulties.

In closing, I would like to thank Francoise, Doug Christensen, and Jim Leveque for helping us out on some of our initiatives and if there is anyone in the audience who is interested in purchasing any of our speciality items, give me a card indicating the item and I will be sure to see that you get a good deal.

Thank you very much.
WASTE DISPOSAL - THE ANSWER TO ACHILLES

Presented to

THE CANADIAN NUCLEAR ASSOCIATION

32ND ANNUAL MEETING

1992 JUNE 9, SAINT JOHN

by

EGON R. FRECH

Manager, Corporate Communications, AECL
As the title of this paper suggests, the so-called waste management "problem" is widely viewed by the public as the Achilles' heel of the nuclear industry. It is one of the main concerns raised by those opposed to the continuation or expansion of nuclear power. AECL public opinion research shows that two-thirds (66%) of the Canadian public says that nuclear power would be more acceptable as an energy source if a permanent solution could be found for the disposal of nuclear fuel waste.

In order to understand this public perception, one has to look at its genesis. When the issue of nuclear waste first surfaced as a matter of public concern in various countries in the early to mid-1970s, it was in response to proposals to construct thousands of nuclear reactors to supply the energy that would be needed by continued industrial growth at levels that are now generally accepted as unreasonable.

The sheer quantity of the waste that would have been produced by a nuclear power program of that size was unsettling to the public. So were reports at the time that fallout from atmospheric nuclear weapons testing was beginning to have a global radiological impact.

Alvin Weinberg spoke of the need for either a "perfect technical fix" or a "nuclear priesthood" to ensure the safety of the waste in perpetuity.

Responding to this public concern, a number of governments passed so-called stipulation laws, saying that no more nuclear reactors could be built until the permanent disposal of the waste they would produce was assured. This moratorium idea was also suggested in Canada, by the Ontario Royal Commission on Electrical Power Planning.

The response of the nuclear industry was to offer a hitherto unprecedented solution, the "perfect technical fix". Because so little waste would be produced for such a great amount of energy, it would be economically feasible to manage it in a way that would create no burden whatsoever for all future generations.
Such a solution was, and remains, entirely outside the realm of human experience. In fact, it is not even conceived as possible for other waste producers in our society. Ironically, nuclear critics point to the longevity of some elements in nuclear waste, while our civilization routinely "disposes of" non-radioactive wastes with infinite half-lives in facilities that require continuing institutional control. Public opposition to nuclear power plants causes electrical utilities to build coal-fired generating stations instead. The waste from those is sent up smoke stacks, and some of it is "disposed of" directly in people's lungs.

After some 15 years of scientific research, the nuclear industry now has the promised technical solution in hand. It can demonstrate, through the use of sophisticated computer models, that nuclear waste can be safely and permanently disposed of in stable geological formations in a way that won't require continuing care and control by future generations. In both Sweden and Switzerland, independent review agencies have issued pronouncements that the case is proved. The governments of those countries endorsed the findings.

As well, a technical working group of the OECD's Nuclear Energy Agency has issued a collective opinion that the means exist to evaluate the environmental impacts of deep geologic repositories for high-level nuclear waste. While some of the technical detail remains to be resolved, the principle of safe geological disposal has been clearly established, and there is an international scientific consensus that it will work.

The Achilles' heel of the nuclear industry should now be armour-plated. The waste management question should no longer be an impediment to the continued peaceful use of nuclear power for the benefit of mankind. But what has been the practical effect?

In Sweden, the nuclear industry proved in the late 1970s that its waste could be safely disposed of. The public responded by voting in a referendum shortly afterwards to phase out nuclear power. In 1980 the government passed the current law, which calls for nuclear power to be phased out by 2019.
Recently, Sweden has started re-thinking this position. But what did this recent change of heart have to do with the waste management issue? There has been start on disposal of low and intermediate level waste, and slow and steady progress on high-level waste management. There has also been a surging realization of the continued need for nuclear energy. Swedish unions, for example, started to express concern that a reduction in the electricity supply would mean a loss of Swedish industrial jobs.

The Swiss case is similar to the early Swedish experience. The government determined that the technical case had been proved for the safe disposal of all classes of nuclear waste. And, as in Sweden nearly 10 years earlier, this was closely followed by a moratorium on the further expansion of nuclear power.

Ontario seems to provide yet another example of this phenomenon. Just when AECL announced that it had enough confidence in its waste disposal concept to present it to an Environmental Assessment Panel for review, the new provincial government put a moratorium on the construction of additional nuclear power plants.

Recent public opinion data gathered by the Angus Reid Group for the CNA shows that there has been a remarkable increase in Canadian public support for nuclear power over the past year. This despite the fact that only about a third of Canadians (29% this year vs 32% a year ago) believe the nuclear industry can manage and safely handle its wastes.

In every country, despite increased scientific confidence in the technical feasibility of geological disposal and despite the extremely low calculated risks from the activity, there is great difficulty in finding disposal sites and actually starting disposal.

You may be asking yourselves what is going on here: surely if waste management were the Achilles’ heel of the nuclear industry, then growing scientific confidence in the safety of geologic disposal should be leading to greater acceptance of nuclear power. Instead, scientific confidence in the waste disposal concept seems to generate moratoria on nuclear power, and when public acceptance of nuclear power does increase, it seems to do so almost independently of any change in public opinion on waste management.
One of the reasons may be that the public doesn't believe the assurances of the scientists that the problem is solved. A "demonstration" by means of computer models, no matter how sophisticated, is unlikely to be as convincing as doing the real thing. In a 1986 AECL survey, only 19% of Canadians said that they felt computer modelling without a physical demonstration of disposal would be enough to assess its safety.

Of course there is a problem with providing a physical demonstration. A system such as a nuclear waste disposal vault, where nothing moves for thousands of years, can't be physically demonstrated during the typical attention span of most members of the public. Nevertheless, even if the physical demonstration would not be scientifically meaningful, there may be great benefit in terms of public acceptance. The public, unlike scientists, often judges things more by how they subjectively feel rather than by their technical descriptions. The Swedish public, having the actual experience of a low and intermediate level waste disposal vault, shows a much greater acceptance of the idea that the waste can be safely disposed of than the public of any other country. More than half of all Swedes now agree that if scientific research shows their area to be the best place for a disposal site, they would accept it.

But the issue may be more complex than this. In volunteering the "perfect technical fix" to the waste disposal problem, the nuclear industry may have inadvertently overlooked the question of whether there are deep-rooted psychological causes for the public's concern about nuclear energy.

The psychological aspects of the acceptance of new technologies have very little to do with technical facts, no matter how well established they may be by scientific consensus or how well they may be confirmed by independent review agencies. The apparent lack of association between scientific confidence in nuclear waste disposal and public acceptance of nuclear power may signify that the waste disposal "problem" merely provides a handy expression of a more deep-seated concern about nuclear energy as a technology that is perceived to be complicated, hard to control and potentially dangerous. In other words, if people are concerned about nuclear energy, they may be more likely to see the waste disposal issue as a reason for not expanding the industry, whereas if they are supportive, they may be more inclined to dismiss the waste disposal "problem" as one that can be readily solved.
If we accept that there may be psychological causes for the public’s reluctance to support nuclear waste management solutions as well as nuclear energy in general, we should ensure that our strategies for answering the public’s concern recognize and deal with these factors. One of the keys to public communications, after all, is to give the public answers to the questions that really concern them.

Fifteen years ago, Canada and Ontario commissioned the physical sciences to develop a technical solution to the permanent disposal of nuclear fuel waste. They have done that job admirably, only now to be faced with the fact that the public acceptance problems remain as difficult to deal with as ever, and are rather impervious to scientific confidence in the technical solutions that have been developed.

One approach to this dilemma may be to put the social sciences to work on these problems -- in the same way we put the physical sciences to work on the technical problems. We don't need to start from a zero information base. Data obtained from limited sociological research over the past few years gives some clues as to where the solutions may lie.

One area that must be addressed is the question of ethics. People won’t accept a waste disposal solution they don’t think is fair and just. In this area, the industry has already addressed the main issue: that it is the responsibility of the generation that creates a waste to manage it in such a way as to not pass on an unreasonable burden to future generations. This principle was always one of the main underpinnings of the Canadian nuclear fuel waste management program.

Research by AECL on the ethics of nuclear waste management shows that although we may not know all of the technical answers, and even though there will always be some uncertainty about undertakings with such long time-frames, the ethical course of action for the present generation is to do the best that it can with the knowledge it has.

This does not mean that the industry has to be able to guarantee that it has anticipated every eventuality. But the industry has to do what it can to discharge its responsibilities, and it has to act in an environmentally responsible way. This can be interpreted to mean starting disposal, or at least starting to provide a physical demonstration, rather than relying only on arguments that "we could do it if we wanted to." It may mean
allowing for future generations to exercise control over what they inherit, and to anticipate that they might modify or even reverse today's decisions if that is what they deem to be the right thing to do. The key principle here is that the present generation can make decisions only on those things over which it has control; we cannot bind future generations to our decisions.

The nuclear industry has a good waste management program: the waste is now and has always been well managed and no member of the public has ever been hurt by it. There is no environmental urgency to move with undue haste because there is no environmental crisis in nuclear waste management. The present storage systems can be continued for as long as people want. The nuclear industry accepts its responsibility to do something more permanent. There are a number of options, including future recycling of the used fuel. A start can be made on physically demonstrating disposal without foreclosing those options for future generations. We have the time to do the job right.

However, the public, because of its past experience with technological failures and its expectation that there will be better technology tomorrow, is wary of the "perfect technical fix". AECL's sociological research shows the public prefers control, monitoring and the possibility of remedial action. These are generally accepted as being the attributes that bring the public's perception of risk closer into line with actual risk. Does that mean the industry should simply continue the present monitored retrievable storage systems? Doing that, and nothing more, would imply a future requirement for the "nuclear priesthood" to watch the waste in perpetuity, which is clearly unacceptable to the majority of the public and to Canada's nuclear regulator. That is exactly what the groups opposed to nuclear energy want: a "solution" that perpetuates the problem.

Our industry clearly has the moral responsibility, the technical capability and the financial means to do something more: to implement a solution that does not pass an unnecessary burden on to future generations. But it cannot implement permanent disposal if the public remains fundamentally uneasy. The optimum solution seems to be moving gradually from storage with extensive monitoring and fairly easy retrievability to permanent disposal with minimal monitoring and more difficult retrievability. This change can occur as confidence in the robustness of the disposal vault increases with more experience. It's a solution that starts with the "priesthood" and moves gradually toward the "perfect technical fix", at a rate determined by both increasing scientific confidence and public acceptance.
The Canadian disposal concept was designed to meet a set of regulatory requirements patterned after the "perfect technical fix". To get a licence for disposal, a proponent must show that the disposal system will be safe without institutional controls. In other words, it must not rely on the "nuclear priesthood". It doesn’t necessarily follow, however, that the system must prevent future generations from monitoring or undertaking remedial action. The public’s desire for more control can be met in a number of ways. There can be staged implementation, with public involvement in decision points along the way as a disposal site is chosen, as permission is given to start emplacing waste, and as decisions are made on various stages of decommissioning. Lack of confidence in the environmental assessment at any stage along the way could be cause for reconsideration.

In conclusion, there appears to be some evidence that waste disposal is perhaps not the Achilles’ heel of the nuclear industry that it was once thought to be. A public belief that the energy is necessary and a recognition that nuclear power is environmentally friendly may override any concern about waste disposal.

There appears to be little evidence that scientific proof of the feasibility of waste disposal, and reviews by even scrupulously impartial scientific and environmental panels, will have much impact on the public’s perception of whether or not the problem is solved. Actual physical demonstration of disposal, or implementation of a system that will lead to disposal, will likely be much more convincing to the general public than additional expressions of scientific confidence. I know that one shouldn’t mention geographic areas when speaking of nuclear waste disposal, lest someone immediately jump to the conclusion that the area mentioned is the proposed disposal site. But on this issue, it sure looks like the majority of Canadians are from Missouri - they gotta be showed. And it’s up to us to show ‘em.
SESSION 5

FUEL AND ELECTRICITY SUPPLY

SESSION CHAIRMAN

Peter Brown
Energy, Mines and Resources Canada
ONTARIO'S DEMAND SUPPLY PLAN - THE GREAT DEBATE

Randy Hurst
President
Canadian Electricity Forum
#3 - 900 McKay Road
Pickering, Ontario
L1W 3X8

Thank you for the opportunity today to address the issue of the Ontario Demand Supply Plan. I was going to title today's speech: "The Future of Electricity in Ontario", but I decided that would be too presumptuous. I then thought how about "Natural Gas in Ontario: The Future is Yours", but I realized this would be delivered to a nuclear industry audience. So I've decided to let Bob Rae title my speech: "Canada's Nuclear Industry and the DSP: Don't Supply Power".

While I was asked to express my views of what I think Ontario's energy future holds, I thought, that depends on what kind of future is in store for Ontario. Allow me to comment for a few moments on Ontario's energy past. I ask this because I think it's important to keep one eye in the rear view mirror and the other eye on the road ahead.

Let me begin with a general statement that the health, direction and progress of any power system reflects the society which it serves. When you have political instability, that is, successive changes in governments with differing energy policies, this instability will inevitably be reflected in the power system which governments govern and control.

The reality is that for many decades in Ontario there was a series of governments dominated by one party that believed in building electricity manufacturing plants and using Ontario Hydro as a tool for economic development. Don't make the mistake of assigning this philosophy the property of the Conservative party. For 100 years now, provincial political parties of every persuasion across Canada have acted on this philosophy and have used publically owned electric utilities to stimulate economic development, create jobs and win elections. In many ways you owe your job to this philosophy when you work for a Canadian electric utility.

In fact, electric utilities in Canada directly employ more than 100,000 people and hundreds of thousands of others are employed by companies who supply equipment and services to the electricity producing industry. In New Brunswick, for instance, the utility is one of the province's largest employers. In this province, electricity export revenues exceed that of the forest industry.

While the Ontario Conservatives were in office for more than four decades, provincial opposition parties, (lobbied and supported by
special interest groups like Energy Probe and the natural gas industry), took issue with government energy policy, its management of Ontario Hydro, and the utility's CANDU nuclear power program. You can't blame them for that, it's the job of opposition parties to do this and also a career for many individuals involved in special interest groups. These interest groups, for the most part challenged what they called "conventional thinking".

They represented a different direction in power planning that favoured a number of unproven, small scale, high-cost alternatives such as cogeneration, combustion turbine units, and wind, solar and biomass energy sources over the traditional mix of hydroelectric, fossil fuel and nuclear generation.

I don't think the people of Ontario for the most part cared especially for the soft energy path and nuclear moratorium when they voted NPD or Liberal. For the most part, Ontarians have been oblivious to the electricity supply issue. They only notice electricity when the lights go out and when their bills go up. But this, I predict, will change. Ask yourself who was happy with the way things used to be:

1. Large industrial and commercial electricity consuming companies who relied on a relatively inexpensive and reliable source of electricity supply and who invested here on the promise from government that they could count on the philosophy of power at cost.

2. Residential customers who were served with a safe, reliable supply of electricity at a relatively low cost, especially when faced with heating with natural gas.

3. Electrical equipment manufacturers and wholesalers, consulting engineers, electrical contractors, and electricity related industries who participated in the building of an electricity-intensive society.

4. A number of U.S. utilities that were able to take advantage of an over-capacity here and purchased electricity from Ontario. These exports assisted Canada's balance of trade, and helped to subsidize Ontario's electricity rates by as much as 7 per cent at one time. For U.S. utilities, it was an expensive but politically easier option than building stations there. Their nuclear program had failed, investors had become disenchanted with the prospect of long term return on investments, and special interest groups and environmentalists had prevented new generation capacity construction. These states turned to Canada and B.C., Manitoba, Ontario, Québec and New Brunswick were only happy to build today for export what couldn't be used for domestic consumption.
5. Successive governments who created the policy environment to make all of the above mentioned groups happy and successful.

Who was unhappy with the way things were?

1. Groups like Energy Probe, Friends of the Earth, Pollution Probe, and Greenpeace, whose views of future energy supplies were contrary at every turn to the established norm. They were, and still are reactionary in their approach and bitter perhaps that they had no real power and impact on the controls that direct our electricity future in Ontario.

2. Groups like IPSO who represent private generators, foreign investors, consultants, and the financial community who were looking for private generation investment opportunities in Ontario where, of all provinces, the most opportunity exists to further their interests.

3. The natural gas industry who saw their product compete poorly against electricity based on price and efficiency. They complained that electricity was unfairly subsidized in the marketplace and that the playing field wasn't level.

4. Provincial opposition parties who constantly criticized the Ontario power system but lacked the political ability to institute their energy philosophies, strongly influenced, I might add by groups 1, 2, and 3 mentioned above.

With all this in mind, is it any wonder that when the NDP government came into power, many in the electrical industry (like the insurance industry) saw their industry in for a very rough ride. Well, I can tell you that all of the efforts of the past two governments to reform and supposedly improve the car insurance scheme in Ontario, the current system is worse. Fewer people are satisfied, no one is adequately protected and rates continue to rise. Unfortunately, the same is going to happen to Ontario's electric power industry. Life is peculiar. You only make things worse when you try to fix something that isn't broken.

When the NDP announced it moratorium on nuclear power construction, I remember watching Norm Rubin from Energy Probe smile confidently, and comment that he never thought the day would really come. I sat there and thought of how he would feel 30 years from now when Ontario purchases its first foreign designed nuclear reactor because our CANDU industry had died and the next generation has decided to take the nuclear path.

That's a bit about where we have been. So, you ask, where are we going? It very much depends on who you listen to. In the current debate and struggle for control of tomorrow's energy vision, there is a different prediction from every camp. AMPCO has one. EEMAC has one. CNA has one. Energy Probe has one.
IPSO has one. NDPers have one. Liberals have one. Conservatives have one. Each vision has a different destiny, only time and the course of events will determine which vision is best for Ontario. But all of these groups are focused on the future. What about the present?

Ontario has recently been and will continue to undergo substantial, fundamental economic change and decline in the strength of its manufacturing base.

In the past two years, there have been a number of leading Ontario manufacturers who, for a number of reasons, couldn't stay in business. Poor sales, yes. But also consider our high taxes: federal, provincial and municipal. Consider our poor productivity. High labour and employee benefit costs. High interest rates. High dollar. Free trade. Cross border shopping. Companies faced with this climate are not amused at the prospect of a predicted 44 per cent increase in electricity rates in the next three years. Any large Ontario electricity consumer would consider this just one more reason to move elsewhere. Any large electricity consuming industry looking to invest in Canada would look to Manitoba and to Québec because of their electrical package.

When this recession is over, many of the companies I have noted above won't be back. Those jobs are lost. Ontario must earn those jobs back, must fight for those jobs and the only way this will happen is by providing enough reasons for companies to invest in Ontario. It won't happen by scaring companies with energy insecurity and high prices. And that's exactly how Ontario industry sees things. They are not as concerned with the debate between traditional and soft energy path strategies as they are about staying in business, meeting payrolls, paring down their cost per unit of production, competing in shrinking market. Survival. Day after day after day.

Ontario industry adopts energy efficiency in order to assist with plant efficiency and plant productivity. They don't concern themselves with energy politics. They save energy because they're in the business of staying in business. They don't want to save energy so that Ontario Hydro doesn't have to build a generating station. They don't save energy to help Ontario Hydro meet its DSM targets. If they can't get a two-year payback from their electricity efficiency investment, the capital will be spent elsewhere. And when electricity is saved, the plant manager doesn't get that money to spend on other projects. His budget is still cut. That's the reality of energy management in industry today.

Let's turn now to the Ontario Hydro 1989 Demand Supply Plan and its 1992 Update.
Let's take a look now at what the Rae government has in store for Ontario Hydro and the province's electrical industry.

The 1992 Update to the original 1989 Ontario Hydro Demand Supply Plan doubled targets for demand management and non-utility generation and by doing this, the Ontario government has avoided its responsibility to commit Ontario Hydro to any new construction for the next 12 years.

The updated DSP has almost doubled demand management targets from the 1989 target of 5,500 megawatts for a new target of 9,800 megawatts. This will be needed by the year 2014 in order to meet an expected annual average load growth of about 2 per cent.

In the meantime, Ontario Hydro plans to double its original investment of $3 billion in demand management programs to $6 billion by the year 2002 to achieve this new target. The problem with this is that while Ontario Hydro plans continued investment in electricity efficiency programs for the industrial, commercial and residential sectors, the bulk of the increase of the 4,290 MW of demand side management target won't come from electricity conservation, it will come from "fuel switching". This means convincing electricity consumers to switch from electricity to other fuels, including oil and natural gas, where gas is available.

Critics of this plan point out that this fuel switching isn't truly energy conservation but merely energy consumption transferred from one fuel source to another. Their other criticism is that this new fossil fuel consumption will increase the province's contribution to carbon dioxide emission and other greenhouse gases.

The update has also increased NUG targets for the same period to 4,200 megawatts from 2,100 in the 1989 plan. In fact, Ontario Hydro can't keep up with all the proposals from industry to supply power to the grid. This year alone, Ontario Hydro turned down more than 20 proposals. The problem with non-utility generators isn't supply, it's price. As the price of electricity increases, it makes this otherwise expensive non-utility generation price competitive. Now I'm not against competition, God knows, but since the past two Ontario governments abandoned the philosophy of power at cost, rates have gone up dramatically. The Rae government has the people of Ontario convinced it is all the fault of Darlington but that's not the whole story. True, the commissioning of units at Darlington and problems there have had an impact on rates. Hell, Milan Nastich predicted that to me 8 or 9 years ago. The reality is that all the other options to Ontario Hydro building new generating stations can't be financed with low electricity rates. That goes for energy conservation, non-utility generation and fuel switching.
There was also the proposal to purchase 1,000 megawatts of electricity from the proposed Manitoba Hydro Conawapa generating station and this remains unchanged in the update plan. Ontario Hydro did plan to develop 2,800 megawatts from new hydraulic resources. One third from Adam Ba-k redevelopment and the other two thirds from northern Ontario. What has been dropped is 1,000 megawatts of new construction in northern Ontario. The government did this because they didn't want to fight native communities on the Moose River system. What makes the government think that Manitoba will be any more successful with their native groups? Doesn't anyone know Conawapa is aboriginal for "Stop Great Whale!"

The 1989 plan called for the construction of more than 5,000 megawatts of fossil fired generating capacity and more than 8,000 megawatts of nuclear generation by the year 2014. The current update plan falls in line with the nuclear moratorium. The 1989 plan also called for the retirement of 6,600 megawatts of fossil fired generation and 2,000 megawatts of nuclear generation. In the update plan, continued life extension programs will mean that only 2,300 megawatts of fossil fired generation will be retired while all of the planned 2,000 megawatts of nuclear generation will be retired.

I question whether the DSP projections for the future are accurate. In my estimation, utility power planning forecasts are accurate only in broad terms. There is a need for flexibility in planning and I question how much flexibility there is in the current plan. Flexibility in the past meant that Ontario Hydro provided for all reasonable load forecasts. This isn't the case now. In the next 15 years, if Ontario's annual load grows at the same rate as it did for the past 15 years, the current plan will not work. The inflexibility in the current plan stems from the fact that there is no political will in Ontario for Ontario Hydro to commit to a construction plan of any kind. The irony is perhaps that DSP probably won't be taken seriously and hence probably won't work if electricity prices remain low and if there is an active construction program in place. It is sort of do or die. I keep asking: "What's the downside to the current plan?" I think the downside to a power plan based primarily on demand side management policies is high electricity costs, shortage of supply, imports from other grids, and an aged and outdated power generation system.

To me anyway, it sounds remarkably similar to the current state of the power industry in many parts of the United States. It may not be what we wished for, but that, I think is the downside of the current plan. By choosing to go the route the U.S. has gone, we will have abandoned the path that has made our Ontario power system a leader in Canada and the envy of the world. Mediocrity awaits those who lack the political will to build for the future.
What would I prefer to see? I'd like to see Canada get its act together. For one, we have not been able to develop a national energy strategy. The federal government has abandoned any interest in doing this to individual provinces, which has only served to fractionalize our energy interests. What about a national electricity strategy? The adoption of a strategy that would see the development of a stronger export strategy, that would encourage electrification of rail systems and automobiles, that would encourage more east/west electricity trade, and a greater commitment to the advancement of our Canadian nuclear power technology and the sale of that technology to other nations. What about a common approach to rate structures, time of use and seasonal rates that would help give industries in different parts of the country the same competitive advantage. What about national standards for electricity efficiency, power quality, and utility rebate programs to industrial customers. This is a model for government, industry and labour to work toward.

But don't mistake what I'm saying as a call to government to do this alone. Essentially, I see government as cheerleader, referee, traffic cop. Not traffic cop, auto maker, road builder, driver, and pedestrian. Just traffic cop. Government should be able to create the right climate through strategic planning with industry in order to best support what industry must and wants to do. Compete and be successful in a changing global environment. Instead, what federal and provincial governments have done is to burden industry with taxes and regulation to the point where it is having the opposite effect. Canada is a great place to live but a crummy place to invest if you want to build something to sell around the world. Instead of being a nation of doers, of makers, of builders, we have become a nation of borrowers and purchasers.

Which leads me to the subject of power planning. Some see the development of an electrical infrastructure as economic growth supported by debt but I say it is prudent investment in the future. Like it or not, the world will be forced to turn from fossil fuels to electricity (mostly from nuclear power) in the next century. Like it or not, industries that are electricity intensive will want to invest where electricity is cheapest.

The dream merchants want us to believe that we can have whole stations worth of capacity at less cost than building them. But remember, this DSM investment of six billion dollars in itself will create no revenue, just debt. DSM is being touted as a panacea for all our energy problems. Forty years ago, dream merchants of another time and another ilk sold nuclear power as solving all our energy problems. Now, I'm not knocking nuclear power, I'm saying dreams are not rooted in realism and that's what we're sadly lacking these days. Honesty and realism.
The dream merchants want us to believe that Canada is moving from an industrial-based economy to a service-based economy but I tell you the strongest economies in the world are not supported by legions of accountants but by legions of engineers who are responsible for building things. Without a strong manufacturing base, we will slip behind the ranks of leading countries in the next century. We must, therefore, think big. Do big things. Build big things. Challenge ourselves to do more than we think we can do, not less.

We manufacture electricity from water, electricity from coal, electricity from natural gas and oil, we manufacture electricity from uranium. Electricity is a manufactured product, manufactured in electricity manufacturing plants and sold to nearly every Canadian. Electricity manufacturing has a $1 billion dollar a year export market in the United States. Not only is electricity a product, in order for it to be delivered reliably and safely, it requires the manufacture of a wide assortment of high voltage and low voltage products. The electricity manufacturing infrastructure is a powerful engine for economic growth. At least as important to Ontario as its automobile manufacturing infrastructure.

For better or worse, the Canadian power planning philosophy at the beginning of this century had a vision of power at cost and a purpose to sell electricity to every home, office and factory in the country. Today, the power industry in Canada is used by everyone like a lifeline and yet it is the whipping boy of every career intervenor, disgruntled environmentalist and those who think design, development, and construction are four letter words. In Ontario, political ideology has taken precedence over common sense and has opened a difficult chapter in this province's history.

This current Ontario plan:

* Only serves to defer the inevitable decision to build more electricity manufacturing plants, especially nuclear,
* Only serves political indecision,
* Only serves to unnecessarily drive up the cost of power,
* Only serves to leave a less reliable system for the next generation of power planners,
* And only serves to burden our children with the responsibility of doing tomorrow what should have been done today.

Thank you for your patience. I think I have time for questions, if there are any.
OVERVIEW OF THE PROBLEM

The electric utility industry began as a dispersed, decentralized, community-based operation with small production and distribution systems. As demand for electrical energy grew, the industry evolved toward greater centralization, larger developments and stronger transmission interconnection of generation and load centers.

Decisions regarding the matching of electricity supply with demand have always been influenced by many conflicting issues and competing priorities. Consumers require high quality reliable service at a competitive price while at the same time there is growing concern about the impact of human activities on the environment.

Conflicting Objectives

This imposes three major constraints on the matching of supply and demand:

1. minimize cost
2. maximize reliability
3. minimize environmental impact

Each of these embodies different variables which often work against one another. For example the primary objective of minimizing cost may in fact be beyond the financial capability of the utility or bring an unacceptable level of financial risk.

Reliability depends upon adequate levels of supply capacity, the operating characteristics of the system and security of power plant fuel delivery. It is always necessary to balance this objective against cost. Reducing environmental impacts adds constraints that often increase costs and tends to reduce system reliability. Consideration must be given to different supply resources which have different costs, lifetimes and operating abilities. Finally the separate resources must form an operating system which can meet the continuously changing demands of all the customers.
Characteristics of Demand

The demand imposed upon the electric utility system is the sum of all end-use requirements of the various customers, plus the losses incurred in the production and delivery of energy to these customers. These demands change from moment to moment and the power balance equation dictated by the laws of physics must be met by varying the inputs to the power system. Each change in customer demand requires a change in the system generation output. Figure 1 shows the 1991 demand curve and corresponding load duration for NB Power. The power demanded is defined by the curves while total energy is measured by the area under the curves.

Figure 1

(a) NB POWER IN-PROVINCE DEMAND 1991

(b) NB POWER LOAD DURATION CURVE 1991
The load duration curve illustrates how base load is that part of the demand which occurs most of the time while the peak load which occurs in the winter in New Brunswick is up to 20% duration. The intermediate load between 20% and 80% is that cycling portion of the demand which varies from week to week and season to season.

HISTORICAL DEVELOPMENT

From the beginnings of the utility industry in the 1880s until the late 1960s, the real cost of electricity steadily declined. This was due to low rates of inflation for fuel and capital, technological innovation, and economies of scale as generating units became larger and more efficient. While the early power system engineers recognized the value of interruptible load and demand controls, they also understood that in a time of declining costs and economies of scale, increased consumption would drive rates down. This emphasis led to numerous marketing programs and special rates to increase load and increase load factors.

Economy of Scale

During this period of increasing demand the matching of generation supplies to demand was relatively easy. Reliability was handled by providing a reserve capacity margin to cover for units which may be forced out of service. Within the operating constraints required for reliable cycling of generation to meet the varying load it was generally cheaper to build larger more efficient plants. These could supply base load requirements while the older less efficient units were relegated to seasonal, peaking or reserve status. Table 1 illustrates this phenomenon of economy of scale for NB Power where heat rates have improved while unit sizes have increased.

<table>
<thead>
<tr>
<th>Unit</th>
<th>In Service Date</th>
<th>Size (MW)</th>
<th>Heat Rate (btu/kwh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grand Lake #5</td>
<td>1951</td>
<td>5</td>
<td>18400</td>
</tr>
<tr>
<td>Grand Lake #7</td>
<td>1953</td>
<td>15</td>
<td>14400</td>
</tr>
<tr>
<td>Courtenay Bay #1</td>
<td>1961</td>
<td>45</td>
<td>11800</td>
</tr>
<tr>
<td>Dalhousie #1</td>
<td>1969</td>
<td>100</td>
<td>9600</td>
</tr>
<tr>
<td>Coleson Cove</td>
<td>1976</td>
<td>335</td>
<td>9300</td>
</tr>
<tr>
<td>Belledune</td>
<td>1993</td>
<td>443</td>
<td>9200</td>
</tr>
</tbody>
</table>

Traditional Supply Planning

In the late 1960's the economies of scale began to saturate, inflation and fuel prices began to increase and the real price of electricity began to rise. The New York blackout illustrated the high degree of society's dependence on electricity and resulted in increased pressure to improve the reliability of service.
It became increasingly necessary to consider the type of generation required to best match the demand. The nature of the load and the mix of generation in a system became more critical. A simple way to illustrate this is by comparing the fixed and variable costs of different types of power plants. Table 2 and Figure 2 provide a life cycle unit cost comparison of a combustion turbine, a coal plant and a nuclear plant. The turbine is most efficient for low capacity factor or peak loads while the nuclear plant is more cost effective for very high capacity factor base load requirements.

<table>
<thead>
<tr>
<th>Table 2</th>
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<tbody>
<tr>
<td>Levelized Lifecycle Power Cost Comparison (1995 $/KW/yr)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Combustion Turbine</th>
<th>Coal Plant</th>
<th>Nuclear Plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Cost ($/kw-yr)</td>
<td>75</td>
<td>250</td>
<td>500</td>
</tr>
<tr>
<td>Variable Cost ($/Mwh)</td>
<td>110</td>
<td>40</td>
<td>7</td>
</tr>
</tbody>
</table>

Costs at different Capacity factors ($/KW/yr)

<table>
<thead>
<tr>
<th>Capacity factors (%)</th>
<th>0%</th>
<th>20%</th>
<th>40%</th>
<th>60%</th>
<th>80%</th>
<th>100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Combustion Turbine</td>
<td>75</td>
<td>268</td>
<td>460</td>
<td>653</td>
<td>846</td>
<td>1039</td>
</tr>
<tr>
<td>Coal Plant</td>
<td>250</td>
<td>320</td>
<td>390</td>
<td>460</td>
<td>530</td>
<td>600</td>
</tr>
<tr>
<td>Nuclear Plant</td>
<td>500</td>
<td>512</td>
<td>525</td>
<td>537</td>
<td>549</td>
<td>561</td>
</tr>
</tbody>
</table>

Figure 2

LEVELIZED LIFECYCLE COST COMPARISON

[Graph showing cost comparison for different capacity factors]
But this is only part of the answer because the new plant must be dispatched within the existing system and its relative economics depend on the fuel prices and generation mix of that system. The option, which when simulated in the system produces the lowest system revenue requirement over its life, is the lowest cost alternative for that particular system and will result in the lowest rates for customers.

**Advent of Demand-Side Management**

In the early 1970's inflation, environmental and fuel concerns began to significantly influence costs. The Organization of Petroleum Exporting Countries shocked the world with an oil embargo in 1973. The rampant inflation that gripped industrialized countries drove the cost of electricity from new power plants as much as ten times higher than the cost from existing plants.

Motivated by the possibility of future shortages of fossil fuels, the prospect of large rate increases and an increasing concern for environmental protection, utility system planners began to examine the possibility of demand-side management (DSM) in conjunction with traditional generation alternatives. The combination of supply-side and DSM options which incur lowest cost consistent with other important goals has become known as least-cost, integrated resource planning and is actively utilized by many utilities.[1]

**INTEGRATED RESOURCE PLANNING**

It is more difficult to measure cost effectiveness of DSM than traditional supply-side options. DSM alternatives alter the nature of the load such that a plan with the lowest long-term present worth of revenue requirements, which produces the lowest rates under supply-side planning, may not necessarily produce the lowest average rates for an integrated plan.

**California Tests**

In order to evaluate DSM the "California" tests [2] were devised to view a DSM program from the perspective of different stakeholders. The three most important perspectives are explained here.

The *society (total resource) test* attempts to measure for the society as a whole, the costs and benefits of a DSM program. The benefits considered are the avoided supply and environmental costs. While the program costs are those paid by society as a whole including the utility and the participants. Transfer payments between members of society (like taxes) are excluded from the calculations since they net to zero for all society.

The *participant test* includes as benefits the reductions in the customer's bill for participation in the program and any incentives paid to them by the utility or the government for participating. The costs are any costs they incur as a result of participating including equipment and material costs as well as ongoing operations and maintenance costs.
The non-participant test is the most controversial of all the demand-side management tests. It measures how non-participating customers' rates will change due to the changes in utility revenues and costs created by the demand-side management programs. Benefits include avoided generation, transmission and distribution costs. Costs are those incurred by the utility, including incentives to participants, plus any decrease in revenues from customers participating in the program.

Minimize Rates or Revenues Requirements

Policy makers have come to different conclusions about whether least-cost planning should be an attempt to achieve lowest rates or the lowest present value of revenue requirements. Some have argued it is best to minimize revenue requirements rather than rates while others believe that economic efficiency is best achieved when lowest rates (not necessarily lowest bills) are achieved. Table 3 summarizes the arguments made on behalf of each approach.

<table>
<thead>
<tr>
<th>Table 3</th>
<th>Comparison of Least Cost Minimization Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rates</td>
<td>Revenue Requirement</td>
</tr>
<tr>
<td>Most efficient allocation of resources when utility minimizes rates.</td>
<td>Most efficient allocation of resources when utility minimizes customer costs.</td>
</tr>
<tr>
<td>Views economy as primarily free market.</td>
<td>Views economy as primarily planned market.</td>
</tr>
<tr>
<td>Emphasis on participant test and non-participant test</td>
<td>Emphasis on participant test and total resources test</td>
</tr>
<tr>
<td>Both participant and non-participant must benefit from each program.</td>
<td>Non-participant may lose on some programs.</td>
</tr>
<tr>
<td>Attractive to new businesses.</td>
<td>Existing businesses benefit more.</td>
</tr>
<tr>
<td>Requires less judgement of customer costs/benefits.</td>
<td>Requires more judgement of customer costs/benefits.</td>
</tr>
<tr>
<td>Potential for load growth and reduction opportunities.</td>
<td>Greater potential for conservation.</td>
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After review of these arguments the New Brunswick Public Utilities Board ruled that rates should be minimized and that the non participant test "should be used as a standard against which NB Power's approach may be compared to ensure that no customer is worse off as a result of the adoption of a DSM project". [3]
COORDINATION OF RELIABILITY CONSIDERATIONS

Historically major consideration in the problem of matching supply and demand has been given to the costs of supply reliability. This was the case primarily for two reasons. First load growth was accepted as being a naturally occurring event, and secondly it was assumed that the purpose of the utility was to simply meet this load growth. In the recent past, the state of the economy and global competitiveness has meant that domestic consumers and industrial customers have operated in a lean mode. Consequently increasing consideration has been given to the costs of unreliability, or as is more commonly said to customer outage costs.

Costs of Supply

Supply of electricity has historically been in the hands of the utility which built sufficient capacity to meet forecast demand plus a reserve margin adequate to provide some degree of reliability. This is changing, with non-utility generation (NUG) now becoming a significant factor in the supply side of the equation and DSM becoming a factor in the demand side. In addition environmental concerns play a major role in the siting and choice of type of generating station which may be put in place.

The determination of reliability is more complex as a result of these factors. More and more consideration is being given to quantify the relative reliability values of different components of the system [4] [5]. But it has not altered the fact that increased reliability generally comes about with an increase in the cost of supply, DSM and/or delivery capacity. This relationship is shown as the supply costs curve in Figure 3.

Costs of Unreliability

To the utility, the costs of unreliability are loss of revenue and intangible costs such as goodwill. To the customer, the costs of unreliability are the costs of lost production.

Recently attempts [6] have been made to collect good, solid data on unreliability costs. This has usually been done according to industrial classifications, as well as for residential and commercial. While the costs vary from sector to sector, nevertheless comparable patterns emerge.

When outage costs are combined with the reliability resulting from different levels of installed capacity the relationship shown in Figure 3 as unreliability costs can be developed.

Coordination of Supply and Unreliability Costs

The total cost incurred by the customer, which is the sum of the supply and unreliability costs, is a bowl shaped curve with a minimum as shown in Figure 3. This theoretical minimum defines the point at which supply is optimally matched to demand. At present, the work to date has not precisely established the location of the
minimum point for any system, nor has it established the relative flatness or sharpness of the minimum. Clearly there are many possibilities. If the minimum is very sharp, then it is worth significant effort to get there. If the minimum is very flat, then additional factors such as good will may play a significant role.

Figure 3

CUSTOMER COST Vs SUPPLY CAPACITY

CONCLUSIONS AND FUTURE DIRECTIONS

It is clear from the historical record that the matching of supply and demand initiatives have involved cost as the major consideration. While cost will continue to be the common denominator future directions will involve many additional factors which will influence costs in different ways.

1. Environmental legislation introduces new costs and constraints into the planning milieu which are expected to have major impacts in the future.

2. Demand side management, including its effects, costs, acceptance and evaluation will continue.

3. Non utility generators are an increasingly larger part of the supply mix for many utilities. A major concern is the reliability of a potentially large number of small generators especially those of a must run nature.

4. Accurate determination of outage costs, or costs of unreliability, and the structuring of these into an optimum planning result will require major effort.
REFERENCES


Presentation

to

Canadian Nuclear Association

32nd Annual Conference

by

B. M. Michel

President & CEO
Cameco Corporation

Saint John, New Brunswick
Saint John Trade & Convention Centre
June 9th, 1992
Thank you for the invitation to be here. I am pleased to talk about uranium supply, demand and pricing from the perspective of a producer and to take you back to the source of all nuclear issues—uranium.

To understand the market situation in which uranium producers find themselves today, we must go through the history and development of the industry.

Where are we today?

Today, the average spot price for uranium is at a record low of $7.75 (US) per pound U\textsubscript{3}O\textsubscript{8}. It has been falling steadily for the past five years, continuing a more-or-less downward course which began almost 15 years ago.

During the past five years, uranium consumption in the western world has been exceeding production every year by a considerable margin. Today the annual shortfall is 57 million pounds U\textsubscript{3}O\textsubscript{8} from a consumption of some 125 million pounds.

For the remainder of this decade, reactor fuel consumption in the western world is quite a predictable matter. It will amount to some 1.2 billion pounds U\textsubscript{3}O\textsubscript{8}. About one-third of that, more than 400 million pounds, are not covered by existing sales contracts. So the uranium market offers great opportunities, and in particular for Canadian suppliers as almost half of the uncovered requirements are in the US.

We know that the price is low, we know what volume of uranium will be needed and we know that current western production is not sufficient to meet the demand.

The law of supply and demand would suggest that this ongoing production shortfall should translate into higher prices. But why has this not been the case?

One significant factor affecting the western world uranium industry today is the growing presence of exports from the former Soviet Union, now called the Commonwealth of Independent States, or CIS.

CIS products, whether from current production and inventory or as potential future supply from the dismantling of nuclear weapons, have effectively delayed the price recovery which was predicted by so many experts in the late 1980s.

However, a preliminary ruling two weeks ago by the US government that the CIS has been dumping uranium material in the US market will likely lead to the imposition of substantial duties on CIS imports, making CIS material less attractive to the US market. Even if the final determination is less than the 118% levy which is currently envisaged, the decision certainly sends a strong message to the CIS.
I will come back to the subject of the CIS exports later but for now, I would like to add it to the list of at least five other features of the uranium industry which have contributed to the unusual behavior of this commodity.

• first, is the cost of uranium itself a very small portion — about 4% — of the overall costs of nuclear - generated electricity. That compares with about 50% for coal and about 80% for oil.

• second, uranium, unlike coal for example, is a highly concentrated form of energy that does not deteriorate and is easy to stockpile because it requires little space. It is therefore possible to build up substantial inventories of nuclear fuel.

• third, although uranium is found almost everywhere in the world, mineable concentrations are relatively rare. Few areas have the potential to become competitive, long-term producers of uranium, especially at today's low prices. The situation in Canada is a glaring example of how this has evolved. Production from the lower-grade, high-cost reserves from the Elliot Lake region of Ontario is now being displaced by production from the higher-grade, lower-cost deposits in Saskatchewan.

• fourth, the history of governmental interventionism in the uranium business, first as a result of its military significance and later as a result of its value as a source of energy.

• fifth, the lingering impact of the unrealistic forecasts for requirements which were made in the past.

Since the first commercial nuclear power plant began operation in 1960, the nuclear share of electricity generation around the world has increased to 17%. While this is a significant portion of the electricity pie, there was a time when growth forecasts and therefore, reactor orders, left no doubt about a much more optimistic future for nuclear power.

The pace of reactor ordering increased dramatically worldwide in response to the oil embargo of 1973. Overly optimistic forecasts, such as that provided in 1974 by the United States Atomic Energy Commission, were proven to be off by more than 300% in less than 10 years. It was forecasts such as these which provided the basis for reactor planning, enrichment contracting, uranium purchasing and ultimately, uranium mining capacity expansion.

This situation led to rapidly increasing uranium prices, which reached $43 (US) per pound by 1978.

It became the practice, at that time, for utility companies to contract heavily for future supply and to carry at least a two-to-three-year uranium inventory. This reflected a mind-set in which security and diversity of supply were the paramount considerations when uranium fuel buyers made their purchasing decisions. From their perspective, a fuel shortage would just be unacceptable. There was a strong argument for supply security.
This argument turned out to be justified in the mid-to-late 1970s, for at that time, although several promising uranium deposits had been discovered, new producing mines were almost a decade away. This argument still holds true today, especially considering the long lead times required to turn a uranium discovery into a productive mine. For example, the Key Lake mine in Saskatchewan, took 8 years to go from discovery in 1975 to production in 1983. Today, as the regulatory review process becomes more comprehensive than ever, the time frame to bring new projects from discovery to production has a tendency to be extended.

In the early '80s, it became clear that there would be neither electricity nor uranium shortages. In the five-year period between 1977 and 1982, forecasts of nuclear electric generation made by respected international groups dropped 40%.

Utility companies around the world, which were faced with lower than anticipated growth of electricity demand, reduced, postponed and even cancelled their nuclear reactor programs. Uranium prices began to fall, driving out the higher cost producers.

Then in the mid-'80s, for the first time in the uranium industry, annual consumption exceeded production. Expectations at that time were that with decreasing production, and increasing consumption, prices—which had dropped to below $16 (US) per pound U\textsubscript{3}O\textsubscript{8} — would soon rise to reflect the probable cost of new and needed production.

This did not happen, principally because the inventories accumulated earlier by utilities and governments became available on the market to compete with primary uranium production. Governments and utilities began selling to other utilities or higher cost producers. And within this changing market, brokers and traders and other intermediaries have been profiting at the expense of primary producers.

The spot market values over the years have reflected the prevailing perceptions in the market, soaring to more than $43 (US) per pound U\textsubscript{3}O\textsubscript{8} during times of perceived shortages in the late '70s then dropping to record lows at various times since. Today, the spot price is $7.75 (US), far below the level which would permit any producer to develop new mines and achieve a reasonable return on its investment.

In the past, producers and buyers were not seriously concerned with changes in the spot price because most of the uranium was sold through long-term contracts. This situation is dramatically changed today as the quantities of spot market transactions have significantly increased. Furthermore today, prices in the long-term contracts frequently are based on a formula which reflects the spot market price.

So, by the late '80s, western consumption had exceeded production for several years and commercial inventories seemed to be approaching acceptable levels.

At that time, it was anticipated that a normal supply-demand situation — if there ever was such a state — was likely to emerge in the western world uranium business.
But starting in 1988, the new era of Soviet-US relations opened the western uranium market to exports from the Soviet Union. To gain acceptance from western electric utilities, the Soviets, through aggressive intermediaries, have made increasingly generous price concessions.

These have claimed many victims in the western uranium industry. In the past few years, 12 of 43 uranium production facilities have either shut down permanently or announced plans to close. In a market where annual consumption levels have recently averaged about 120 million pounds U₃O₈, western production has decreased from 95 million pounds in 1988 to about 68 million pounds last year.

Here in Canada, even though total production has been reduced in the past four years, we are now the largest uranium producer in the western world, supplying one-third of production. About 80% of that production comes from Saskatchewan and the remaining 20% from Ontario.

Australia is now Canada's closest competitor, supplying about 14% of western world production.

And most notably, the US has given up its position as the largest producer, dropping its share of western production to about 12% last year from almost 40% in 1980 during the heydays of the uranium industry.

Exports from the Soviet Union which initially amounted to about 4% of western uranium consumption have increased steadily and may now represent up to 15%. These exports take many different forms and are difficult to track, reaching the market in various direct and indirect ways.

It should be noted that all past CIS production figures and inventory volumes have been estimates. Information available today while better is still not verifiable. However, a number of the producing republics have indicated their interest in joining the Uranium Institute. If they do so, they will have to participate in the sharing of information.

While exports from the CIS have effectively delayed the anticipated spot price recovery, and reduced the rate of drawdown of excess western world inventories, we believe that price recovery is inevitable because of the continuing and growing shortfall in western world production.

Last year the shortfall was 57 million pounds. One year earlier it was 45. The year before that it was 33.

These shortfalls have been filled by the CIS exports, as well as by the disposal of excess western inventories.
But this cannot continue indefinitely, even considering the dismantling of nuclear weapons, which contain highly enriched uranium that is likely to be recycled for use in commercial reactors.

In addition, the CIS’s primary uranium production, which was about 25 million pounds U₃O₈ last year, is decreasing, and there is no indication of the presence there of really competitive uranium reserves. As well, the former Soviet Union’s own reactor program consumes some 15 million pounds U₃O₈ each year and this volume is likely to increase in the future as economic order returns, leading to increasing industrial activity and therefore to a new period of growth for electricity demand.

We believe that new western world production will be very much needed in the years ahead. But it will only happen if prices recover enough to secure a profit on new mining projects. How is this going to happen?

To answer that, we must determine where we are now. Then I will take out my crystal ball and make some projections.

I know that all forecasting is dangerous but I also believe that any discussion of the future of the uranium industry is fruitless without using some real numbers and without looking conceptually at various scenarios.

So, where are we now?

Today, we know that western production is below 70 million pounds and is decreasing.

We know that annual western uranium consumption is projected to rise to from today’s 125 million pounds to almost 140 million pounds by the end of the decade. This projection is based on known reactor requirements.

Observers generally agree within 10% that western uranium inventories are about 375 million pounds and that the desired level of inventory is about 200 million pounds.

This level would permit one year of forward supply in the US and more than two years in Europe and the Asia Pacific region. I should note I draw these figures from Kenneth Friedman, a US economist who would be considered an independent, third-party providing an impartial assessment of industry projections. These figures are generally supported by the London-based Uranium Institute.

Using these figures, one would conclude that excess western inventories amount to about 175 million pounds. The projections I am about to make assume that this remaining inventory will be drawn down gradually during the next several years.

As for the CIS exports we believe these were about 20 million pounds last year, and that this volume could, if not restricted, rise possibly to as much as 30 million pounds. We also
believe there are limits to the acceptability of CIS material and that there are limits to what level of exports can be sustained by the CIS.

So the difference between consumption now and supply from western production and CIS exports will be filled by excess western inventories and to a known extent by the well-established capacity of the spent fuel reprocessing facilities.

Looking at all these factors in one picture, it is clear that western production will be needed to fill the gap. You may have to move the lines representing these variables somewhat to adjust to new information, but the fact remains, new production will be required.

Changes in these variables will only impact the date at which new production will be needed, not the fact that it will be needed for sure.

But who will be left to participate in this market?

That will depend on other important factors, notably the uranium spot price, which as I mentioned earlier increasingly affect the contract prices. At a given time, the price will determine which producers can survive, which ones will be forced out, and which ones will enter the market. In addition, the uranium price may determine what levels of production producers can supply without reducing the return on their investment to unacceptable levels. At today's spot price of $7.75 (US) per pound, it is ludicrous to expect any of the few remaining producers to bring new uranium production on stream. At $15 dollars, that will change. And at $20 per pound, the composition of the industry will be entirely different.

So let us see what might happen in the future at various price levels. Different parts of the supply side of the industry will respond differently, affecting the overall picture of supply and demand.

I will warn you again that these are forecasts which are subject to change. They are just presented as possible scenarios.

In 1995

At $10 (US) per pound, production will continue to drop, and the remaining supply will be nearly split between excess western inventories and CIS material. I should note that all references to CIS material in these projections include very small amounts from China and Czechoslovakia.

At $15 dollars per pound, production will increase. Existing producers will expand production, and some of those who withdrew from the market earlier may re-enter. It is unlikely that new producers will enter the market at this time as new facilities may not yet be ready for production and the financial rewards from new projects would be too low. If available and marketable, CIS material will continue to be attractive at this price, and western inventory
drawdown will continue, but at somewhat smaller volumes because the overall inventory is being depleted.

At $20 dollars per pound, the same scenario exists but on a more pronounced scale. Everyone will want a larger share of the market. Current producers will expand production, new and former producers will prepare to enter or re-enter the market but, again, new facilities will not yet be ready for production. The CIS should continue to occupy a substantial part of the market and the supply from excess western inventories will be reduced as the overall excess inventory level diminishes. In addition, in times of higher prices, fuel buyers will be more inclined to retain larger inventories as security.

In all of these cases, at $10, $15 and $20 dollars per pound, there is still a shortfall of supply. However, as I noted earlier, a favorable final ruling by the US government concerning the anti-dumping charges could change the picture dramatically, reducing imports from the CIS. Such an action could make these predictions unfold sooner and trigger a rapid increase in uranium prices.

In 2000

By the year 2000 we have a story of extremes as the difference between supply and demand is much more pronounced. Excess western inventories will have been depleted so that one source of supply has now been eliminated.

At $10 per pound, western uranium producers will essentially disappear and even the CIS, assuming that it has made the transition to a market economy by this time, will not find it economical to sell uranium at this price.

At $15 per pound in the year 2000, new lower-cost production centres, which have recently come on stream, will become new sources of supply and the CIS presence in the market is likely to have stabilized at about 20% of the market. This still leaves a shortfall of supply.

At $20 per pound, many more new producers may enter the market, and contribute to a new cycle of oversupply. The CIS will continue to provide substantial volumes, just to maintain their market share, but at this price they will no longer be the preferred supplier.

What we see emerging from this information is that new uranium production is going to be needed in all cases and that the lower-cost producers, those in the $15-range and below, will be more able to survive and do well.

In addition, we see that a high uranium price does not necessarily mean uranium market stability, and that high prices lead to greater supply for a limited non-elastic demand. This, as we have seen here, could lead once again, in the next century, to a temporary oversupply situation reminiscent of what we have known in the past.
These projections are based on known requirements and throughout this exercise, we have not considered developments in the nuclear industry which would have an impact upon the demand beyond 2000.

And in examining the industry so closely, let us not make the mistake of overlooking the obvious for the period beyond 2000, and that is that what we need are more reactor orders. The future of the uranium industry is tied to the future acceptance of nuclear power.

However, your neighbors and mine will hesitate to accept a reactor in their community unless they are convinced it is safe.

I believe in the public's mind, safety has become synonymous with being small. Two decades ago, it was different. Megaprojects were supposed to be the engines of prosperity and were closely linked with success. Today, society appears to be afraid of growth. It appears to distrust megaprojects and associates these with environmental damage, uncontrollable costs and a lack of concern for the general public. Today, if I may quote author Ernst Schumacher: small is beautiful.

I am a miner who has spent the past 25 years as a student of the mining business and I would not presume to give advice to an audience with experience in engineering and marketing of reactors.

But if I were a designer and marketer of reactors I would go for the excessively safe, small-size reactor even if the multiple redundancies in safety make the small-scale reactors less efficient from a technological perspective. I believe that the nuclear industry cannot be oblivious to what other industries know too well. Offer people what they want, even if it is not what you really think they need.

In the 1990s, there is a mood of safety and environmental awareness on which we should capitalize. In spite of a concerted effort against the industry by anti-nuclear lobbyists, public support of nuclear power is flat or increasing, primarily because of its environmental advantages. I believe that the nuclear option will increasingly benefit from this fact, especially as other sources of electricity such as coal and hydro are subjected to the same scrutiny that the nuclear industry has been accustomed to throughout its history. It is in this domain of safety and environmental protection that the nuclear industry excels, so we must continue to emphasize this fact.

Only growing public acceptance of the nuclear technology can rejuvenate our industry and bring it back to the prosperity it needs so much.

- End -
SESSION 6

IN WHICH DIRECTION SHOULD REACTORS ADVANCE?

SESSION CHAIRMAN

W.B. Lowenstein
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IN WHAT DIRECTION SHOULD REACTORS ADVANCE
LESSONS FROM OPERATIONS

A. R. Johnson
Station Manager
NB Power
Point Lepreau

INTRODUCTION

Despite the title of this paper, it is not intended to discuss possible reactor (or even CANDU) design advances other than in the broadest sense. It is also not intended to review lessons learned at Lepreau in its first 10 years. Our input on the first topic has been given to AECL who are presenting a paper at this conference, and our thoughts on the second have been detailed in other papers and reports (references 1 to 3). Instead, the author has taken the liberty of interpreting the title to provide a paper that discusses "In Which Direction should Point Lepreau Advance - Lessons from Operations". It is believed that this will be of interest to others.

NB Power is a Crown Corporation with responsibility for generating and distributing electricity within the province of New Brunswick. It has a total generating capacity of 3200 MW, comprising about 53% fossil fuelled, 27% hydroelectric and a single 630 MW(Net) CANDU nuclear power station at Point Lepreau which represents the remaining 20%. Point Lepreau first generated electricity in September 1982 and was declared "in-service" in February 1983. It has achieved a capacity factor of 91% since first electricity and 93% since "in-service".

POINT LEPREAU - THE UTILITY'S PERSPECTIVE

For an electrical utility, the decision to build and operate a nuclear power station, is primarily a business one, although political considerations may also play a major role. In simple business terms, the utility is looking for the ideal investment - maximum benefit for minimum financial and human risk.

Since New Brunswick Power is a Crown Corporation, the benefit is to the New Brunswick rate payer, and the benefit to the rate payer is maximised if both capital and operating costs are minimised. The risk is also to the rate paying public. The financial risk is minimised by ensuring that the power station is not incapacitated by damage to components that are difficult or prohibitively expensive to replace and by a sensitivity to possible regulatory developments or public opinion. The human risk is minimised by ensuring that the power station does not sustain accidents that can threaten the public or the environment.
Other papers at this Conference will address capital costs, regulatory developments and public opinion. This paper addresses the topics of operating cost and risk and indicates where effort should be placed to reduce both.

POINT LEPREAU - ANNUAL COST

Since cost is one side of the cost-benefit comparison, it is necessary to determine where the money is spent and it is therefore useful to review in relative terms, the capital and operating components of the annual cost to NB Power of Point Lepreau. It is also of interest to consider how the plant's capacity factor can be a potential cost or potential benefit.

Figures 1, 2 and 3 illustrate the breakdown of capital, and operations & maintenance (O&M) costs for the 1990/91 fiscal year.
It can be seen that the initial capital cost of the station (and subsequent capital expenditures), along with the associated depreciation of this capital, are the largest financial burden associated with the plant. Minimising the construction and commissioning schedule is critically important to controlling capital cost, but this is a topic for another paper.

It is also apparent that those O&M Costs that are controllable, are dominated by labour costs. This paper will quickly show that although labour costs must, of course, be controlled in a business-like manner, if efforts are made to severely curtail them, the utility will be unable to achieve results in the area that is of most significance - Capacity Factor.

Figure 4 shows the performance of Point Lepreau since start up in September 1982. It has consistently achieved a very high Capacity Factor.

Figures 5 & 6 show, respectively, the Average 1991 and Lifetime capacity factors of the different reactor types, with Lepreau shown in comparison.
The significance of these Figures is illustrated by the following statistics.

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<th>1991 Comparison</th>
<th>Lifetime Comparison</th>
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<tr>
<td></td>
<td>CANDU Average Capacity Factor 66%</td>
<td>CANDU Average Capacity Factor 67%</td>
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<tr>
<td></td>
<td>Point Lepreau Actual Capacity Factor 98%</td>
<td>Point Lepreau Actual Capacity Factor 91%</td>
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<td>Extra Revenue Generated $51 Million</td>
<td>Extra Revenue Generated $331 Million</td>
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It is clear that the benefit of operation at Lepreau's capacity factor rather than an "average" capacity factor, is substantial, and it is also clear that an extended forced outage at Lepreau would be a major financial cost.

DIRECTIONS FOR IMPROVEMENT IN OPERATIONS

The Point Lepreau CANDU 600 has reached a design maturity which, coupled with mature operating practices has resulted in an exceptionally high capacity factor. The design can also satisfy existing requirements for nuclear and personnel safety. With the approaching technical resolution of the Pressure Tube problem (albeit late for operating reactors), only regulatory developments should demand significant design changes. It is evident, then, that the present reactor design can be operated at near perfect capacity factor, within the necessary safety and environmental constraints. Consequently, design innovations that can significantly improve Point Lepreau's predicted O&M costs or operational safety are not easy to identify and there would appear to be little incentive to look for such improvements. However, complacency is a dangerous state of mind, and our success to date must only serve to make us look harder for improvements. The following is a discussion of areas for such improvements.
O&M COSTS

Management of O&M costs is, of course, an on-going task for Operations, but only regulatory requirements remain as unpredictable challenges, and in most cases, even the unavoidable costs associated with new regulatory developments can be dwarfed by the effect of the plant's capacity factor. At Lepreau, for example, a 1% increase in annual capacity factor would "finance" an extra 30 employees! An increase of 3% in annual capacity factor would pay for the entire Safety & Compliance budget!

Maintaining, and if possible, improving capacity factor is therefore seen as the priority in managing O&M costs.

Figure 7 shows the Lepreau generation losses from startup to the end of 1991. The contribution to lost output from unplanned outages is minimal.

By far the greatest contribution is the annual maintenance outage. Recognising this, NB Power has devoted a great deal of effort and imagination to outage planning and management, and has achieved a considerable reputation for it's expertise. This does not mean that improvement is not possible. The obvious first question to ask, is whether we need to do the work that is dictating a shutdown, and then to examine ways to eliminate the work, to do it in a shorter time, or to do it on line.

A review of the 10 planned maintenance outages from startup to 1992 shows that the major critical path jobs were either turbine-generator maintenance, pressure tube inspection and maintenance, or Reactor Building Pressure Tests. Other significant routine work carried out during Lepreau shutdowns is electrical bus/switchgear maintenance, fuelling machine maintenance, valve overhaul, containment liner painting, steam
generator maintenance, ISI, safety system testing and various design changes.

Each task that regularly or predictably consumes critical path time needs to be identified and carefully studied to determine how its effect can be minimised - first in the design phase, and then in the operational phase. For example, initiatives to develop wet scraping, faster channel inspection, faster channel defuelling and ultimately, on-power inspection all justify serious technical and financial consideration. Special safety system testing, the inability to perform NDE examinations on-line, the desirability of alternate power supplies to key heat sink equipment, crane capability in the turbine hall, and so on, are all design or development areas worthy of attention. Furthermore, the maintainability of "outage critical" equipment and systems can often be improved.

In addition to improving the efficiency of outage work, maintenance strategy should be moving toward predictive maintenance (with increasing use of diagnostic equipment) and reliability based maintenance. This should ensure that maintenance is done only when it is required, and only when equipment failure will affect operation or safety. Design changes must receive particularly rigorous review if they require an outage for installation; with test requirements, operating documentation, training, and risk, all being important considerations.

With outage maintenance work minimised and optimised, outage duration and labour costs will both be reduced and the task of planning and controlling the outage will be easier. Our experience has shown that we have the organisational structure and planning and scheduling tools to manage, hour by hour, the detail, sequence and interdependence of as many as 3000 jobs. We have also been successful in maximising productivity by careful attention to schedules, supervision and communication. However, we do not yet have effective tools to easily anticipate developing critical path problems, or to recognise, communicate and implement, at short notice, changes in logic or priority. We plan to develop and implement such measures.

Effective outage planning is one of the most vital components in maximising capacity factor and providing the resources, planning and tools to achieve it should be a continuing priority with plant operators.
RISK REDUCTION

Although Lepreau has performed well, there is no guarantee that as the plant ages, failure to monitor and control the condition of equipment and systems will not lead to expensive damage. It is also no guarantee that the ever-present risk of a major accident will not become a reality. These risks are minimised by operating and maintaining the equipment so that it continues to function (often called "systems health monitoring") and managing it's status so that it is available when required.

The Generic Monitoring System

In order to ensure that a complex industrial facility performs with very high availability, it's equipment and systems need careful and continual attention. As the facility ages, attention needs to given more frequently and more intelligently.

Although the operations and maintenance groups identify equipment failures and fix them, it is the system engineer, who, through continuing responsibility and accountability for the system's well being, becomes familiar with it's behaviour and is best able to diagnose and anticipate problems that may develop. The system engineer's involvement in design changes, trouble shooting, training, deficiency review and documentation provide the experience to become the "expert".

This powerful concept has served Lepreau and other utilities well, but it can be improved. It does not allow for effective pro-active decisions, nor for a comprehensive understanding of system operation because the system engineer must rely on intermittent data from tests and limited personal observations. What is needed is the ability to monitor and diagnose the condition of the system on-line, to have access to historical data of the system engineer's choice and to have the tools to select parameters for study and to perform manipulation of data. All this must be done in a way that is transparent to the operators.
The key to achieving this is to bring the plant parameters to the system engineers desk in real time, and to provide computer capability to receive and analyze the parameters. The technology to achieve this exists and at Lepreau has been named the Generic Monitoring System.

An ethernet system with appropriate servers and interfaces allows the system engineer (and others) to gain access to on-line data from the station control computers as well as other data acquisition units such as the safety system data logger and the chemistry computer.

With data access provided, the system engineer is provided with extensive tools to manage the data. This includes trending, data logging, alarming, historical review and mathematical treatment of raw data. This is supported by user friendly interfaces and a CAD package for customising reports. Figure 8 shows typical outputs from the system.

This powerful monitoring tool is of no use if it is not used intelligently and aggressively. This is the area that needs development. A review of plant systems and their critical parameters would lead to a set of objectives that would then be realised by the system engineer in a program of monitoring. Of course the system engineer would be free to, and encouraged to develop areas of interest based on observation of the system, knowledge of maintenance and design changes etc. In this way, equipment and system performance can be examined in depth, leading to early recognition of problems, better diagnosis of incidents, better historical data and better and more dedicated understanding of system behaviour. All this with no involvement
of control room staff, no manual transcription or manipulation of data and no paper to be distributed. In this way, the system engineer can at last take full advantage of the powerful and comprehensive data gathering capabilities of the plants on-line computers.

Handheld Computers

The Generic Monitoring System brings the plant computers to the system engineers desk. Handheld computers can complement this by effectively taking computers into the field with the operator and the maintainer. These devices can collect field measurements and maintenance and test data in electronic form and this information can also be provided to the system engineer. In written form, the task of analyzing and trending data becomes too cumbersome and time consuming to be practicable; in electronic form, the task is manageable and the system engineer can once again take full advantage of available information to preserve the health of the plant systems. This technology is well established. It only needs imagination to make it effective in the nuclear industry.

Chemistry Control

A particularly important form of "systems health monitoring" is that associated with chemistry control. Many utilities have come to rue the day they neglected to care for their steam generators, steam piping, service water systems, primary system components etc. Corrosion and the products of corrosion can result in very expensive damage to equipment and long outages for repair or replacement. Predictably, as the plant ages, these problems arise more frequently and in more serious form.

Resources, organisation, field and laboratory instrumentation, procedures, training and data acquisition and analysis are all essential components of an effective chemistry control program and they must be in place as early as possible, but effective monitoring of the plant systems is the first and most important goal.

The Generic Monitoring system described above is the essential on-line tool used at Lepreau for chemistry monitoring and off-line data is also a component of the chemistry data base. The gathering of this data in a powerful and flexible computer format is an important start, but the full benefit will only be gained when the data can be carefully analyzed to give early predictions of developing problems.
Predictive Maintenance

Predictive maintenance has been discussed as a method of avoiding unnecessary maintenance, with consequential benefits in reducing outage work. The other strength of predictive maintenance is, that with diagnostic tools and techniques, it can predict developing problems or impending failures. The most well developed of these techniques is vibration monitoring, but rapid advances are being made such areas as diagnosis of electrical equipment problems, valve operation and noise analysis. Non-destructive examination remains a major form of predictive maintenance, and the increasing sophistication of eddy-current and ultrasonic inspection has opened new possibilities to ensure the health of equipment.

In order to maximise the benefits of predictive maintenance, utilities must carefully select the systems and components whose failure will be significant, and must then, where possible, put in place a predictive maintenance program that will give confidence that failures will be predicted.

Managing the Status of Equipment

A familiar aspect of nuclear power plant incidents, is the failure of standby or poised equipment to perform as intended. The inclusion of redundancy by the designer does not always seem to bear fruit in practice.

The failure of equipment to perform as expected, is usually the result of an inability to control the status of critical equipment such as valves, circuit breakers and protective devices, the failure to properly test equipment after maintenance, the failure to promptly follow up deficiencies and the existence of unidentified or incorrectly installed temporary design changes.

The systems used to control the status of equipment are invariably paper based and in seeking to provide tight control but operational flexibility have become increasingly complex and convoluted. Figure 9 shows the Point Lepreau Jumper Record form, an example of a component of a complex paper system that has often not been effective.
In many cases, the systems are not understood, and they are not used rigorously because the significance of many aspects of the procedures is not realised. The defence in depth often provided by the procedures can, in this way, be confounded.

In order to improve this situation, two initiatives need to be developed. First, a thorough "business" analysis of the system must be completed, to understand the flow of information, the constraints, the inputs and outputs, the users, the records and so on. For critical systems, human factors specialists should be involved in development of the "business" model. This stage is necessary to create a streamlined, logical and effective process. Once this is complete, computers should be employed to support the user in carrying out the tasks. The computer is unequalled in its ability to store and access data, to present to the user only the information needed, to be precise, to be rigorous, and to be tireless. In all of these aspects, the human can, and will fall short.
Procedures

Procedures are an essential aspect of nuclear plant operation. They are essential because they define the approved way of doing things. Being approved, of course, does not necessarily mean being the best; but a process that requires a standard format, multidisciplinary review, a model that can develop with experience, and consistent and predictable implementation does give the best chance of success.

Procedures cover a broad range of critical tasks. They include Emergency Operating Procedures, standard operating manuals, maintenance procedures, reference documents, station instructions, test procedures, work plans and technical unit procedures. Using or referring to these procedures is a continual activity as the plant and its documentation are managed and it is obvious that the quality of these procedures will affect the success of the activities.

We have, generally, succeeded in developing technically correct procedures, but only with Emergency Procedures have we made any serious attempts to apply human factors principles to make the procedures usable, and yet we observe that it is the use of "day-to-day" procedures that frequently leads to or contributes to serious accidents.

It is obvious that if you do not initiate accidents, you do not need to use Emergency Procedures (and you do not damage equipment or have to shut the plant down). We should, therefore review our non-emergency procedures on a plant wide basis, select those that are critical to safe and economic operation and review and upgrade their usability. Again, the computer should play a role in relieving the user of demands that strain humans.

The special case of Special Safety Systems

In discussing risk, there is a tendency to think of economic consequences such as equipment damage or plant shutdown. There is also a tendency to assume that our special safety systems will work, firstly because we establish confidence in their availability through testing and secondly because they are so rarely called upon to act "in anger". Accidents that lead to special safety system action, let alone accidents with failure of special safety systems, are believed to be the exclusive territory of the analysts and not the "real world".
This tendency to complacency must be countered. Our responsibility to preserve the integrity of the special safety systems must not be driven by the regulator. It is essential that everyone who works at a nuclear plant understand the role of these systems and their overriding importance to real safety. Attention must be given to monitoring and assuring the health and availability of these systems, to the quality of their operating, maintenance and test procedures, and to the training and awareness needed to ensure that everything associated with the special safety systems is, in fact, special. To reach the necessary level of perfection to achieve this goal is not merely a matter of saying it should happen - it needs innovative thinking.

The special case of Emergency Procedures

Perhaps the most significant single advance in reactor safety over the past 15 years has been the recognition, following Three Mile Island, that many serious plant incidents occur because the operator is unable to understand what has happened to the plant and therefore cannot determine the corrective actions or their priority. This recognition led to the development of concepts variously described as "symptoms based response", "state approach", "critical safety function approach" etc. These concepts all rely on the fact that the "health" and ultimate "survival" of a complex dynamic system can be reduced to a series of high level prioritised objectives. These objectives can in turn be satisfied by monitoring and controlling a relatively small set of parameters (referred to as Critical Safety Parameters (CSP's) at Lepreau). The objectives can be addressed without the need to diagnose the cause of the incident. An equally important conclusion was that the human operator was a crucial and unavoidable participant in the sequence of any serious accident.

The principal product of this approach has been the development of "Symptoms Based" Emergency Operating Procedures. These procedures provide a technical solution to the problem of stabilising a misbehaving nuclear power plant, and human factors techniques have often been used to provide assurance that the operator can actually use the procedures to achieve this end. Finally, simulator exercises have been used to train and familiarise operators with the procedures and plant behaviour that accompanies these incidents.

Despite these developments, concerns remain. The symptoms based EOP is invariably the ultimate safety net. It must work. Establishing and maintaining the technical and human factors quality of EOP's requires a rigour and attention that is difficult to maintain. To provide controlled and auditable testing, there is a tendency to teach
and practice a predetermined and limited set of plant upsets whereas actual upsets are invariably different. Training and procedures often cannot easily address operator errors in procedure execution. Instrumentation used in the procedures may not be sufficiently reliable or redundant. There is the risk that operators will lose confidence in their own procedures when they are under stress, overriding them because they "know better".

To raise EOP's to the consistently high level that is necessary requires that high priority and constant attention be given to all aspects of generating, verifying, validating, training on, and implementing EOP's. Design changes should be made, where relevant, to support the procedures. Testing and maintenance should be such as to give confidence that EOP equipment stays healthy and available. Finally, operators must be trained with a comprehensive understanding of CSP's; why they are chosen, how they are measured, where they are displayed, how they are controlled, how to identify unacceptable trends and how to restore them to acceptable values, how to avoid initiating upsets in CSP's and last, but not least, to understand the significance of failure to control such upsets. This type of training leads to operating staff who can react capably, predictably and confidently to any serious upset, regardless of whether they had ever practiced the particular event.

Human Factors

In concluding this paper, this ubiquitous topic is seen as an increasingly important and an increasingly obvious factor as we strive to achieve near perfect operation and maintenance and near zero risk. The critical and unpredictable human element becomes evident as equipment and system designs mature, leaving the human being as, potentially, the most powerful and yet the weakest link in the chain. In exploring the improvements to capacity factor and risk, human factors have been seen as a key component in the solutions, and designers, manufacturers and operators must try to effectively and practically apply human factors principles in their work. For their part, human factors specialists must work with the nuclear industry, not as mere advisors, who critique what is presented to them, but as pro-active contributors, who give firm and unequivocal direction to their colleagues.
References:


1.0 INTRODUCTION

CANDU nuclear power plants have established an enviable record in the safe, reliable, and economic generation of electricity since first entering commercial services in the early 1970s. However, past performance is not sufficient for the assurance of future market success; CANDU must continue to evolve to meet emerging market requirements. These run the gamut from safety and environmental issues to economic and financing concerns.

To date CANDU evolution has focused on safety enhancement, including the defence in depth approach to the mitigation of postulated accidents, plant simplification through the reduction of the number of components and arrangement of systems, and the improvement of constructability and maintainability. These advances are embodied in the CANDU-3.

In the near future evolution of the established and successful CANDU technology will continue, with emphasis on safety enhancement, cost and schedule reduction, plant simplification, and the confirmation of alternate fuel cycles. In parallel, design effort will focus on the CANDU-9, a single unit CANDU plant with an electrical output in the range of 900 MW. The CANDU-9, while utilizing proven systems, components, and design parameters, will take advantage of the evolutionary technologies as they become available. The CANDU-9 design will accommodate larger core sizes and alternate fuel cycles, thereby enabling the output of future plants to be increased to the 1200 MW range.

In the longer term CANDU technologies will continue to evolve to satisfy the requirements of a rapidly changing world. In following sections, requirements that may prevail in the year 2020 are briefly discussed, and potential responses by CANDU technologies are identified.
2.0 NEAR TERM CANDU DEVELOPMENT

2.1 General Objectives

2.1.1 Enhanced Safety

In the past, the need to mitigate hypothetical accidents that could severely damage the plant or endanger the public have dominated CANDU safety considerations, leading to the provision of "defense in depth" safety features. While maintaining this approach, new CANDU designs will place increased emphasis on minimizing the probability of accidents.

This can be accomplished in many ways including:

- Making the plant less susceptible to equipment failure. For example, by utilizing improved pressure tube materials, steam generator tube material, enhanced system chemistry, or by improving equipment design (pump seals for example).

- Making the plant more tolerant to equipment failure. For example, use of higher strength calandria tubes to reduce the possibility of calandria tube failure in the event of a pressure tube failure, or increasing the reliability of steam generator heat sinks.

- Improved man-machine interface. Advanced technologies facilitate the design of operator friendly control centres that enable the operator to easily and clearly assess any necessary information, thereby reducing the potential for error and permitting faster response.

Improvements outside the control centre are also possible. For example: bar code identification of all equipment reduces the potential for maintenance errors and facilitates tracking.

In CANDU plants, the moderator surrounding the fuel channels provides defence against core meltdown in the event of a loss of coolant coincident with a loss of Emergency Core Cooling. However, the calandria is also surrounded by a large water filled shield tank; new designs will optimize this additional heat sink to provide additional safety capability for the highly improbable severe accident scenarios.

2.1.2 Capital Cost and Schedule

Regardless of other attributes, it is necessary for nuclear plants to be economically competitive with alternate energy sources. This requires both short construction schedules and acceptable "overnight" costs.
The CANDU 3 made major advances in these areas through, component and systems simplification, extensive use of modularization and shop fabrication, and the use of advanced computer based design and information management technologies. Future CANDU designs will continue these thrusts. In addition, renewed focus will be given to reducing the procurement time for major components in order to reduce the project schedule.

2.1.3 Plant Simplification

The evolution of CANDU reactors from the prototype Douglas Point station to current plants has featured a blend of increasing complexity on the one hand, primarily in the areas of safety and safety support systems, and simplification, primarily in the process systems area, on the other hand. Future CANDU designs will give a renewed focus to simplification, particularly in terms of operation and maintenance. In most cases this effort will lead to reductions in the number of components and systems, but in other cases the addition of a component may lead to overall simplification.

The further use of passive systems may also contribute to simplification and will be evaluated. For example, AECL research is developing passive catalytic recombiners to cater to post-LOCA hydrogen.

2.2 Alternate Fuel Cycles

The unequalled neutron economy afforded by the heavy water moderated CANDU reactor facilitates a wide variety of fuel cycles. The natural uranium fuel cycle is currently utilized in all operating CANDU plants for a variety of reasons, including the low cost of uranium in today's markets, the ease and simplicity of fuel fabrication, and independence from enrichment requirements.

When uranium prices escalate, CANDU utilities will have a number of alternate fuel cycles to choose from, including a once through cycle utilizing enriched fuel (≈1.2% U-235). This cycle provides a three fold increase in burnup while reducing uranium resource consumption and maintaining the simplicity of a once through cycle. AECL is well advanced in the development of the 43 element CANFLEX fuel bundle, which can achieve current bundle powers with a lower peak element rating; this bundle is suitable for various alternate fuel cycles.

Alternate fuel cycles, which may be of particular interest to utilities already operating light water reactors, involves the use of spent LWR fuel as a basis for CANDU fuel. Options
include mechanical reprocessing and repackaging of LWR fuel, the use of recovered uranium from LWR fuel reprocessing plants, and the use of both recovered uranium and plutonium from these reprocessing plants.

With more advanced fuel cycles, CANDU can operate as a near breeder, thereby dramatically conserving uranium resources, while maintaining the simplicity of a once through fuel cycle.

3.0 IN 2020

3.1 Background

Mankind is quickly accelerating the world environment into totally uncharted territory. For example:

- Half of the people to live beyond age 5 ever born are still alive.
- More nonrenewable resources have been consumed by mankind in the last 50 years than in the previous 100,000 years.
- In 1960, countries with the richest 20% of the world's population consumed resources at a rate 30 times greater than those with the poorest 20%. By 1990 this disparity had more than doubled to 62 times, with the wealthiest 20% of the countries consuming 83% of gross world product.
- Gross world product increased more than 3-fold, from less than 7 trillion dollars (1990$) in 1960 to more than 22 trillion dollars in 1990, with a corresponding increase in resource consumption.
- World population increased by 74%, from 3 billion to 5.3 billion, between 1960 and 1990, and a further 2.5 billion increase in world population is projected by 2020; 99% of this increase will be in developing countries.

Obviously these trends cannot be sustained. The developed countries must go beyond the provision of surplus foodstocks and minimal medical aid to developing countries and bring them into a trading network that will allow their standard of living to improve.

Attention must be given to protecting the environment by limiting emissions and waste production, and by protecting land and water masses from environmental risks and damage. Since developed countries generally occupy the resource rich lands above and below the tropics of Cancer and Capricorn, and developing countries are generally situated in the resource
barren intermediate territory, expanding world industrialization while precluding the need to excavate the developed world to obtain resource materials will be a challenge.

3.2 Requirements

In determining the requirements for future nuclear power plants, it is important to look sufficiently far into the future to establish the necessary direction and focus, but not to look so far into the future as to make the conclusions meaningless. In this paper, the year 2020 is considered. Setting down a list of needs (by the world population) in 2020 is fairly easy. For example, the effort to serve the mushrooming requirement for raw materials while limiting the environmental impact will give a new meaning and focus to the "3Rs" of Reduce, Reuse, and Recycle, and the term waste will have a new meaning, being limited to only those components and byproducts of used materials that have absolutely no anticipated value.

The need for very large additions to the world's electricity supply is obvious, consistent with minimizing environmental impact. However, setting specific requirements for industrial facilities, including nuclear power, is considerably more difficult.

The nuclear power plants being built in 2020 will be designed by today's graduates, and operated by today's children. Some insights can therefore be obtained by recognizing their views and priorities.

The requirements for nuclear plants in 2020 are likely to include:

- Fundamental improvements in safety that would preclude any requirement for public evacuation or relocation following an accident.
- Minimizing the environmental impact of the energy cycle (including mining, transportation, manufacturing, site utilization, and waste management).
- Performance and economics that are consistent with living standard objectives and competitive with all other energy options.

While next generation nuclear plants can make improvements in these areas in an evolutionary and piece-wise manner, the plants of the future, 2020 and beyond, must address all requirements simultaneously and accept revolutionary changes as necessary.
3.3 Nuclear Response

3.3.1 Background

There are two principal aspects of nuclear power that impact on resource utilization; the thermodynamic efficiency and level of heat utilization, and the neutron efficiency.

In water cooled reactors, gains in thermodynamic efficiency are severely limited by the rapid increase in pressure required to achieve higher temperatures, and by the relatively poor heat capacity and conductivity of the uranium dioxide fuel, which leads to unacceptable fuel temperatures.

The family of light water reactors (PWR and BWR) are also limited in the area of neutron efficiency due to the high neutron capture cross-section of the light water coolant/moderator.

Some alternate reactor types such as the High Temperature Gas Reactor (HTGR) overcome the thermodynamic efficiency limits, but do little to improve neutron efficiency. Others, such as the metal cooled fast breeder reactors dramatically improve both thermodynamic and neutron efficiencies, but incur major capital cost increases in both the nuclear plant and the companion fuel reprocessing facilities.

3.3.2 CANDU Capability

CANDU is a very flexible and capable reactor technology, and can respond to new and demanding requirements. For example:

- The separation of moderator and coolant, provided by the channel reactor concept, allows the use of coolants with a high temperature capability at relatively low pressures, thereby increasing possible process heat applications and efficiency, while retaining the neutron economy provided by the heavy water moderator.

- Alternate coolants facilitate the use of alternate fuels with thermal conductivities and heat capacities several times greater than those of uranium dioxide.

- The fuel channel design provides a short conductance route for decay heat rejection from the fuel to the moderator in the event of a loss of coolant accident. Fuel/fuel channel designs that preclude the need for a safety grade emergency core cooling system are possible.
With peak thermal neutron fluxes 30 or 40 times those in a LWR, CANDU can effectively detoxify the actinides and long lived products present in irradiated fuel.

Advanced fuel cycles, including near breeder "once through" cycles can substantially reduce resource requirements, waste volumes, and fuel reprocessing requirements.

The potential for achieving a "zero" discharge facility exists, while safety enhancements can preclude the potential for evacuation or land contamination.

The fuel channel concept facilitates the full scale testing of advanced fuel channel designs, eliminating the need to scale-up or extrapolate test data, or to construct a prototypical plant.

Comparable capability for development does not exist in any other established reactor design.

4.0 SUMMARY

CANDU is an established and successful technology, capable of evolving to meet the new and demanding requirements. Near term evolutionary advances will satisfy current and emerging demands. The challenges are great to refine CANDU to meet the longer term requirements of the technically sophisticated developed world. To meet the needs and conditions of the impoverished and technically unsophisticated underdeveloped world are, however, a much greater. Not only are the answers unknown, but the questions have yet to be defined. However, the need for power to achieve prosperity is clear. Taken in context, successfully rising to the larger challenge could provide the best product for the entire world.

Prudent development will allow CANDU to meet the requirements of the year 2020, and beyond. In the long term neutron efficient CANDU plants, operating in tandem with accelerators or fast breeder fissile material producers could dominate the electricity generation field.

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ADVANCED REACTOR CHARACTERISTICS

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SUMMARY

Technology development is a social process. This fact is reflected in current programs to create advanced reactors. These programs have differing rationales, conceptual strengths and prospects for realization. Concepts promising greatly improved safety have attracted the greatest attention from the public, but likely have the least chances of ever being built. Programs to develop evolutionary reactor concepts, attempting steady incremental advances in both safety and economics, are attracting the bulk of reactor development resources worldwide, but are largely invisible within the debates of different nations concerning the future of nuclear power. Notable gaps exist in many countries between the realities perceived by the public, policy makers, and technologists concerning the prospects and promises of competing power reactor concepts.

Development of a new power reactor concept can be likened to the iterative solution of a complex non-linear equation for which many of the governing relations and data are unknown. In the solution process the design team varies many factors, including system materials, configurations and control parameters; continually seeking improvements over the previous design versions. The basic reactor concept is analogous to the initial guess to the solution. Usually the ultimate design iteration will be different in many details from the initial design, but it will remain faithful to the basic concept. This corresponds to finding the ultimate solution in the neighborhood of the initial guess within the design variable domain. Consequently, since the ultimate solution is likely to be reasonably close to the original solution the basis for formulation of the latter is important.

In formulating a reactor concept development teams often begin with a formulation of the characteristics of a new product which will be attractive to a set of potential customers. The different advanced reactor concepts have differed essentially in terms of these formulations. Any reactor concept must simultaneously satisfy minimal performance goals in terms of both expected safety and economics, and their associated uncertainties. The minimal economic standard is usually the cost of electricity from the best competing technology.

The minimal safety standard is that which a particular society is willing to accept. This standard can change greatly over time, depending upon such factors as economic conditions, national security conditions, the level of trust in institutions and nuclear organizations, and the quality of the recent nuclear power plant operational record worldwide. For example, in the Armenian Republic of the former Soviet Union during the past three years the temper of society has swung from a clamor to shut down its operating reactors (citing concerns about seismic hazards to the reactors) to one of demanding that these same reactors be brought back into operation (citing a need for the electricity which they would produce, coupled with existence of a new social order, even though the seismic data for the region has not changed for the better).
In going beyond these minima different customers will prefer different performance emphases for a reactor concept in terms of improving safety or economics and in reducing uncertainty. The initial reactor concept is then formulated to satisfy what the designer understands to be the customer's demands. Since the ultimate solution is typically similar to the conceptual solution this understanding is then very important in affecting the ultimate directions of technology development. The reactor development problem usually is not stated in these terms, but upon examination it is seen to conform to this description.

The different reactor development programs which are currently, or have recently been active worldwide are listed in Table 1. It is seen that they are grouped according to concepts attempting to make important gains in safety, while remaining competitive economically (the "advanced" concepts); and those attempting primarily to improve economic performance and secondarily to improve safety (the evolutionary concepts). The latter have attracted the greatest investment worldwide and the former the greatest publicity. The latter concepts have been formulated largely in response to electric utility company preferences; the former in reflection of the evaluations by designers of the demands of the general public. If the advanced concepts can be developed successfully (all are now at the design or conceptual stage of development) it will remain to be seen whether the public will actually bestow its acceptance upon promising but unproven technologies.

The advanced concepts are typically of lower power than the evolutionary concepts, because they rely upon passive safety features to accomplish the post-shutdown reactor cooling and containment cooling functions. These features are less effective but potentially more reliable than the active features used for the same purposes in the evolutionary plants. Consequently the maximum permitted power of the core is determined by the maximum heat flux which can be sustained by the least effective safety feature, with the result that the advanced reactor concepts are typically of lower power than the evolutionary concepts. The currently active advanced concepts and their associated passive safety features are summarized in Table 2.

All of these reactor concepts except for the PIUS and MHTGR are designed without containment structures. Rather they rely upon highly reliable core cooling and high-integrity fuel, respectively; in the hopes of rendering the containment superfluous. The burden of proof to show that these functions will be accomplished with low uncertainty may be very great.

The movement to develop advanced reactors is now entering its second decade. It remains to be seen whether any will ever be built. As time passes without an order being placed for such a reactor the likelihood grows that the traditional utility preference for evolutionary plants will predominate. Should this occur the greatest contribution of the advanced reactor effort would likely be the stimulation of reactor designers of all types to reexamine their understandings and approaches for improving safety. In any event it will be interesting to participate in the resolution of these competing approaches to technology development.
Table 1
WORLDWIDE PROGRAMS OF NUCLEAR POWER TECHNOLOGY DEVELOPMENT

PROGRAMS EMPHASIZING PASSIVE SAFETY

**Germany**
- 100 MWe Modular HTGR (Siemens, Brown Boveri) (Inactive)

**United Kingdom and United States**
- 300 MWe Modular PWR (SIR Concept) (Rolls Royce & ABB-Combustion Engineering)

**United States**
- 130 MWe Modular HTGR (General Atomic)
- 180 MWe Modular LMR (PRISM Concept, General Electric)
- 750 MWe PIUS-BWR (Oak Ridge National Laboratory)
- 600 MWe LWRs (Semi-Passive Safety)
  - SBWR (BWR, General Electric)
  - AP-600 (PWR, Westinghouse)

**Sweden**
- 500 MWe PIUS-PWR (ASEA-Brown Boveri)

PROGRAMS EMPHASIZING ECONOMIC PERFORMANCE

**Europe**
- Joint European Fast Reactor (France, Germany, United Kingdom)
- European (1400 MWe) PWR (Nuclear Power International: France, Germany)

**Canada**
- 450 MWe HWR (CANDU 3) (AECL)
- 900 MWe HWR (AECL & Ontario Hydro)

**France**
- 1400 MWe PWR (N4 Project, Framatome, Electricité de France)
- 1200-1450 MWe LMR (Superphenix-1 Project, Novatome, Electricité de France)

**Germany**
- 500 MWe HTGR (Successor to 300 MWe THTR Project) (Inactive)
- 300 MWe LMR (SNR 300 LMFBR Project) (Inactive)
Table 2 (continued)

**Japan**
- 12500 MWe LWRs
  - ABWR (Tokyo Electric Power, General Electric, Toshiba, Hitachi)
  - APWR (Kansai Electric, Mitsubishi, Westinghouse)
- 714 MWt LMR (Monju LMFBR Project)
- Successor to 148 MWe FUGEN LWR/HWR Project

**United Kingdom**
- 1000-1400 MWe PWR (Sizewell-B, Hinkley Point-C Projects)

**United States**
- LWR Requirements Document Project (Electric Power Research Institute)
- 1250 MWe ABWR (General Electric)
- 1200 MWe APWR (Westinghouse)
- System 80+ (ABB-Combustion Engineering)

**ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>BWR</td>
<td>Boiling Water Reactor</td>
</tr>
<tr>
<td>CANDU</td>
<td>Canadian Deuterium Uranium, Heavy Water Reactor</td>
</tr>
<tr>
<td>HTGR</td>
<td>High Temperature Gas-Cooled Reactor</td>
</tr>
<tr>
<td>HWR</td>
<td>Heavy Water Reactor</td>
</tr>
<tr>
<td>LMFBR</td>
<td>Liquid Metal-Cooled Fast Breeder Reactor (version of LMR)</td>
</tr>
<tr>
<td>LMR</td>
<td>Liquid Metal-Cooled Reactor</td>
</tr>
<tr>
<td>LWR</td>
<td>Light Water Reactor</td>
</tr>
<tr>
<td>PIUS</td>
<td>Process Inherent Ultimately Safety (version of LWR)</td>
</tr>
<tr>
<td>PRISM</td>
<td>Power Reactor Inherent Safe Modular (version of LMR)</td>
</tr>
<tr>
<td>PWR</td>
<td>Pressurized Water Reactor</td>
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<tr>
<td>SIR</td>
<td>Safe Integral Reactor (version of LWR)</td>
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### Table 2

**REACTION AND CONTAINMENT ULTIMATE COOLING FEATURES, AND MECHANISMS OF THE ADVANCED REACTOR CONCEPTS**

<table>
<thead>
<tr>
<th>REACTOR CONCEPT</th>
<th>COOLING FUNCTION</th>
<th>PLANT FEATURE/MECHANISM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Water Cooled Reactors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PIUS</td>
<td>Reactor Cooling</td>
<td>Natural convection and evaporation of borated water pool in which reactor is immersed</td>
</tr>
<tr>
<td>AP-600</td>
<td>Reactor Cooling</td>
<td><strong>Transient</strong> – Natural convection to elevated high pressure heat exchanger, with evaporation into containment from immersion pool</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Post-LOCA</strong> – Flow of stored coolant under influence of pressurized gas and gravity to core and evaporation into containment</td>
</tr>
<tr>
<td></td>
<td>Containment Cooling</td>
<td>Natural convection of air about exterior of containment with evaporative assistance</td>
</tr>
<tr>
<td>SBWR</td>
<td>Reactor Cooling</td>
<td><strong>Transient</strong> – Natural convection to elevated high pressure heat exchanger, with evaporation from immersion pool into containment</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Post-LOCA</strong> – Flow of stored coolant under influence of gravity to core with evaporation into containment</td>
</tr>
<tr>
<td><strong>Gas-Cooled Reactors</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modular High Temperature Gas-Cooled Reactor (MHTGR)</td>
<td>Reactor Cooling</td>
<td>Thermal radiation from reactor vessel to surroundings, conduction from surroundings to soil</td>
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<td>Sodium-Cooled Reactor</td>
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<td>Containment Cooling</td>
<td>Natural convection of air around containment exterior and thermal radiation to surroundings</td>
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SESSION 7

CANADIAN ADVANCED NUCLEAR RESEARCH PROGRAMS

SESSION CHAIRMAN

D.H. Lister
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INTRODUCTION

Detailed reports on Canada's fusion strategy and descriptions of the two major components of the National Fusion Program (NFP): Centre canadien de fusion magnétique (CCFM) and the Canadian Fusion Fuels Technology Project (CFFTP), were given at the 1988 CNA conference (1-3). The purpose of this paper is to provide a brief update on the most significant events in fusion R&D since 1988 and their impact on the NFP.

FUSION DEVELOPMENTS

Last year, two key milestones on the path to fusion power were achieved. Both were as a result of experiments (4) on the European Community's Joint European Torus (JET) tokomak device located at Abingdon near Oxford, England.

For the first time, substantial power was produced from deuterium-tritium (DT) fusion reactions. Since JET is scheduled to undergo major modifications in 1992/93, it was necessary to limit neutron activation of the machine structure. Moreover, only a relatively small amount of tritium could be used for the experiments - a total of about 0.2 g (2000 Ci) - because JET's tritium processing facilities were not yet in operation. Thus, only a few non-optimized shots (discharges) with tritium were performed. The tritium was introduced through 2 of the 16 neutron beam injectors that are used to heat the JET plasma; the remaining 14 were used in the normal fashion, i.e. injecting deuterium atoms. The best such DT shot with 11% tritium yielded about 1.7 MW of fusion power over a period of 2 seconds corresponding to an integrated total neutron yield of $7.2 \times 10^{17}$ neutrons.

As a result of these shots, it was found that the techniques used for handling tritium were very effective. Almost all of the tritium introduced into the two neutral beam injectors and about two-thirds of the amount in the interior of JET had been recovered a month after the shots. In terms of plasma physics performance, the DT discharges behaved as predicted from existing plasma transport codes.

In another series of discharges that were optimized with respect to plasma performance, in contrast to the DT shots, a best DT
equivalent Q value of 1.14 was produced in a deuterium plasma. Q is the ratio of the fusion energy produced to the energy required to heat the plasma. Since this result was produced in a deuterium plasma but not in a DT plasma, a "DT equivalent Q" is derived, which means the Q value that would have been produced in a 50:50 DT plasma with the same plasma performance. As noted above, the recent DT shots give considerable confidence in the validity of this type of extrapolation. The attainment of a Q greater than unity constitutes "scientific breakeven", the demonstration of the scientific feasibility of fusion power. Thus, the JET result was a major milestone.

Current plans for JET envisage an extensive campaign of DT shots designed to culminate in 1996 in a series of optimized DT shots with 50% tritium plasmas and power levels in the order of a few 10's of megawatts. The comparable US device, TFTR, is also preparing a series of DT discharges to commence in mid-1993.

THE ITER PROJECT

As reported at the 1988 CNA Conference, the International Thermonuclear Experimental Reactor (ITER) project is a joint enterprise of the United States, the USSR, Japan and the European Community (EC) to design and possibly construct an engineering test reactor - the next stage in fusion power development. The purpose of ITER would be to test all of the engineering technologies required for the practical realization of fusion as an energy source prior to the construction of fusion power plants.

The first phase of ITER, the Conceptual Design Activities (CDA), began in early 1988 and was completed by the end of 1990. The product of the CDA was a conceptual design for ITER agreed to by all the parties. Canada successfully participated in this phase through an agreement with the EC.

The negotiations for the next phase, the Engineering Design Activities (EDA), proved to be more lengthy than anticipated. In part this was due to the political and financial uncertainties that arose from the dissolution of the former USSR. However, it is expected that the EDA agreement will be signed in the summer of 1992.

Unlike the CDA, which was coordinated by a central team located at Garching in Germany, the EDA will be operated at three sites. San Diego will be the central site responsible for project integration, with Garching responsible for the parts of the design inside the vacuum vessel. A third site at Naka, Japan will be responsible for all systems outside the vacuum vessel. The governing body of ITER, the ITER Council, will hold its meetings in Moscow. This complex multi-site arrangement was set up to reflect the various interests of the ITER partners and will no doubt be challenging to operate in a coordinated fashion.
This also implies that there may be considerable difficulty in deciding on an eventual site for ITER construction, if it is decided to proceed to that phase.

Participating in ITER is essential for Canada, not only because the project is at the forefront of fusion development, but also because it offers substantial technological and industrial opportunities. Therefore, negotiations with the EC on Canadian participation in the EDA are now in an advanced stage.

NATIONAL FUSION PROGRAM

Both of the NFP's projects continue to perform successfully. CCFM operates a medium-sized magnetic confinement fusion experiment - the Tokamak de Varennes (TdeV). It is designed to maintain its magnetic fields for much longer than most other tokamaks in the world. This means that long time-scale effects related to plasma performance and materials can be studied, including plasma-wall interactions, control of plasma impurities, long pulse non-inductive current drive and development of plasma diagnostics. CCFM has made significant contributions to fusion since its first operation in 1987 March. Work in physics and diagnostic areas such as soft x-ray tomography, interpretation of "saw tooth" collapse, multichannel interferometry, theoretical models of particle transport and, recently, divertor biasing and experiments with new boronized materials have prompted considerable international interest in CCFM's program. The TdeV is currently exploiting its magnetic divertors (devices that use a configuration of magnetic fields to remove impurities from the plasmas). Work in the immediate future involves increased pumping capacity in the divertor chambers and optimization of divertor biasing for low impurity plasma operation. Future work for long pulse operation involves the design, construction and commissioning of a non-inductive current drive system; this work is now well-advanced. CCFM has contributed physics expertise to the CDA phase of ITER and will continue to participate in this area during the EDA phase.

Canada has specialized expertise in tritium technology resulting from CANDU development, and in robotics and remote handling from participation in the space program. These areas are of particular significance to fusion. The work of CFFTP builds on these "niche" technologies and has led to Canadian participation in major foreign fusion projects. CFFTP's program covers a wide spectrum of R&D activities, performed by industry, universities, provincial and federal laboratories. CFFTP has, in conjunction with CCFM, established a credible technological presence for Canada in world fusion circles. Internationally-recognized contributions are being made in areas such as tritium safety (atmospheric modeling and dispersion experiments), tritium monitoring (development and sale of a variety of instruments), isotope separation systems (development, manufacture and sales), fusion breeder blanket R&D (a world leader), and robotics for the
maintenance of large fusion devices (a major area in conjunction with SPAR). The current world expenditure on fusion is in the order of $2 billion annually and it is to this market that sales of Canadian goods and services are addressed by CFFTP. The current thrust of CFFTP is to develop the commercial and technical opportunities arising from ITER. A plan for CFFTP participation in the EDA has been developed in consultation with the EC that includes work in the areas of fuel cycles, assembly and maintenance (robotics), building and plant layout, heat transport and control systems.

Recently, the federal government approved a new five year funding term for the National Fusion Program. This funding will support Canada's commitment to participating in international fusion programs and provide long-term stability for our fusion effort. Federal funding is provided by the Department of Energy, Mines and Resources, through the Program on Energy R&D. For fiscal 1992/93, total combined fusion funding will be nearly $30 M, when provincial contributions matching the federal funding and funds from other sources are included.

For CCFM, this funding will ensure the centre's long-term viability and the international relevance of its research programs. Completion of the planned upgrades to the TdeV will permit CCFM to perform tasks in support of ITER. CFFTP will use the funding primarily to support Canadian participation in the technological and design aspects of the ITER EDA. Its established R&D activities will continue and CFFTP will also continue this export of Canadian technology to international fusion projects.

CONCLUSION

Recent progress in fusion R&D is very encouraging and has added impetus to the ITER collaboration. Canada's program is well positioned to participate in and benefit from these important developments.

REFERENCES


INTRODUCTION

In these years of heightened energy awareness, utilities are being asked to help their clients reduce consumption. Canada is frequently accused of being an excessive electricity user. This is not strictly fair, because Canada's high per capita consumption results in part, from producing energy intensive materials, e.g. pulp and paper, aluminium and other metals. This explanation of Canada's high energy intensity also points the way to strategies for reducing consumption. The resource sectors, and particularly pulp and paper are obvious targets.

When energy is used in the form of heat, only a small fraction (determined by the Boltzmann distribution) actually modifies the intermolecular chemical bonds. The rest simply increases the temperature, and must be later recovered to maintain a reasonable energy efficiency. Specialized forms of energy, microwaves, laser light, and high energy electrons can couple energy into materials much more efficiently.

AECL has studied the use of high energy electrons for industrial processing of several types; specifically in pulp production and the use of pulp in the cellulose industry. These studies show how energy utilities and industry could work together to create a new less energy intensive process.

HIGH ENERGY ELECTRON RADIATION

Electron beams are created in accelerators, of which, several types have been developed for industrial use. In the simplest, electrons are generated from a heated wire or plate, and are accelerated by a dc voltage. Energies of a few hundred thousand volts are achievable. Such accelerators produce electrons which can penetrate less than a millimetre. Consequently, they find application for surface curing of coatings. In more sophisticated accelerators, the energy of the electrons can be increased to 5 or 10 million electron volts, where the particles can penetrate 5-10 cm into most common materials.

AECL has recently developed high energy (10MeV) electron accelerators to power levels not previously available. This makes it possible to envisage treating products in industrial volumes at high speed. For example, AECL's IMPELA 50kW linear
accelerator can treat approximately 250 tonnes of wood chips per day, in the mechanical pulping application described below.

HIGH YIELD PULPING

The thermomechanical pulping (TMP) and chemi-thermomechanical pulping (CTMP) processes are widely used in the production of newsprint and are specific forms of the more general refiner mechanical pulp processes. In the TMP process, wood chips are softened with steam and introduced into a small space between a stationary plate and high speed rotating plate. The wood chips are literally torn into fibres by the teeth on the plates. Compared with chemical pulping methods, very little wood is lost in the pulping process (i.e. it is a high yield process). This high yield comes at the expense of high electricity consumption. For example, the energy to produce one tonne of Black Spruce pulp is 2200 kWh. For an 800t/day mill purchasing power at 0.03/kWh, the electricity cost per year is $18.5M. While this is significant enough, Black Spruce is one of the least energy intensive species. By comparison the vast stands of fast growing loblolly pine in the Southern USA require about four times as much electricity per tonne of pulp. The electrical intensity of the refiner high yield pulping processes have limited their use to:

a) areas where the species are relatively easy to pulp
b) areas where electricity costs are low.

It has been known since the 1960's that electron beam treatment of wood chips affects their pulping characteristics. This is to be expected, because significant doses of electron beam radiation break molecular bonds and cause chain scission. With the main objective of reducing the specific energy requirement in high yield pulping, the studies have been carried out to evaluate the effects of pretreating wood chips in an electron beam on the specific energy, drainage and physical property inter-relationships of high yield pulps produced from typical North American wood species.

In the thermomechanical pulping treatment of Black Spruce (Picea mariana) and Loblolly pine (Pinus taeda), pretreatment of the chips in an electron beam at a dosage level of 30kGy resulted in significant changes in the specific energy pulp quality interrelationships of the pulp compared to conventional pulping treatment. The main effects observed on the pretreated chips were as follows:

- 20%-30% net reduction (see figure 1) in specific energy at a given drainage level
- reduced fibre length and long fibre content
- increased shive content
- reduced density related strength properties
- reduced tear strength (see figure 2)
Electron beam pretreatment of Aspen chips (Populus tremuloides) at 30KgY prior to chemithermomechanical pulping (CTMP) resulted in significant energy savings, an increased shive content and a reduction in bonding properties. In the case of Aspen CTMP however, there was no reduction in tear strength as a result of the treatment.

Additional trials to evaluate the effect of electron beam dosage level in the range 0-30 KgY on the quality characteristics of Spruce TMP indicated that the changes observed in specific energy and pulp physical properties were directly proportional to the dosage level.

These studies have recently been reported to the Technical Association of the Pulp and Paper Industry and are being reviewed with interest in the pulp and paper industry.

The economic relevance for the pulping of Black Spruce is the energy reduction available. The 20-25% appears very attractive in an industry where a few percentage points saved is very important. However, the accompanying reduction in tear strength limits the situations where the gains could be immediately realized.

It is observed that the very same electron-induced chain scission which makes the chips easier to tear into pulp, also makes the average fibre length shorter and this reduces the paper strength. The strength reductions are not so large that they make the paper unusable. Indeed, in many parts of the world, such paper would be the norm. They are however, too large to simply install an electron treatment plant as a pretreatment stage for pulp destined for existing markets, where the printing rates require the highest available tear strengths.

The opportunity does exist, to apply the electron process in the production of supercalendered and writing papers. These are being pursued with manufacturers.

In a less extensive series of tests on Aspen, the electron irradiation did not reduce the tear strength, and there is an explanation related to the different morphology of hardwoods. The adverse effects on Aspen pulping were minor, and could likely be overcome with existing process technology changes.

The opportunity exists for specialized mills and owners of difficult-to-pulp species to pursue similar test programs to determine the importance of this process in their specific situation.
VISCOSE PRODUCTION

Another electron beam application of interest to the forest products industry involves the production of viscose, a precursor to rayon and other staples. In this process, pulp is depolymerized, dissolved in a carbon disulphide-based process and then extruded as a reconstituted cellulose fibre. Currently the depolymerization stage uses chemicals, atmospheric oxygen and heat. Replacing this with an electron-beam depolymerizer enables the viscose producer to control the molecular weight of cellulose within an exceptionally narrow range. This then permits major process economies downstream. In addition, the electron beam activates the cellulose reducing the quantities of the expensive and environmentally disagreeable chemicals required. It should also permit the use of the environmentally popular oxygen-bleached (rather than chlorine bleached) pulp as source material for viscose production.

More specifically, the e-beam processing of dissolving pulp reduces the chemical demand in the viscose process, most notably the carbon disulphide (CS$_2$), caustic soda (NaOH) and sulphuric acid (H$_2$SO$_4$) demand. Tests have shown the CS$_2$ requirement is reduced by up to 20%, and both NaOH and H$_2$SO$_4$ by up to 5%. Estimates show these savings to amount conservatively to about US$50/tonne viscose product, or about US$3 million per year for an average 60,000 tonne/year viscose plant. In addition, these reductions in chemical demand greatly reduce the impact on the environment, particularly with reference to discharge of CS$_2$. The reduced CS$_2$ usage can also effect the process economics, either through reduced size of CS$_2$ reclamation plant required, or by allowing expansion without additional reclamation capacity.

This application of electron beam processing does not result in direct electricity savings, but it offers reduced heat energy usage, reduced chemical usage and reduced chemical pollution.

STATUS OF ELECTRON BEAM PROCESSING

Both the processes above have been developed to the stage where a pilot plant could be considered. Meanwhile, the industrial use of electron beam accelerators has taken a significant step forward in the past year.

AECL's IMPELA, 10MeV, 50kW linear accelerator prototype at Chalk River has operated at 97% availability levels and has passed 1000 hours of operation.

AECL Accelerators has designed the high power accelerator as a product for commercial sale at its Kanata design office and assembly facility. The first commercial unit has recently been installed at E-Beam services in New Jersey. It is currently being commissioned, and commercial operation is slated for November 1992.
OPPORTUNITY FOR UTILITIES

AECL Accelerators has been approached by a US utility and pulp producer to study the opportunities for demonstrating the energy conservation potential of the electron beam pretreatment of thermomechanical pulp. I offer the suggestion to other utilities attending this annual meeting of the Canadian Nuclear Association.

REFERENCES

Fig. 1 Electron beam treatment of Spruce chips at 30 kGy decreases the specific energy requirement of TMP at a given freeness level.
Figure 2  Effect of electron beam treatment of spruce chips on Tear Index of paper produced at freeness of 100° CS.
INTRODUCTION

Nuclear radiation has the ability to "see" through the body, without perturbing or endangering its functions. As a beam of radiation passes through the body, it is subjected to absorption and scattering by the tissue in its path. Emerging radiation carries differential absorption and scattering information, which is useful for image reconstruction. Diagnostic imaging utilizes change in radiation intensity and/or energy to produce a picture elucidating different properties of body tissues. The images are reconstructed with the aid of a computer.

Imaging methods involving atomic and nuclear radiation include digital radiography, x-ray computed tomography, emission tomography and Compton scatter imaging. The physical principles and capabilities and limitations of each technique are reviewed. Areas requiring further development are also identified.

DIGITAL RADIOGRAPHY

The acquisition of x-ray projections in digital form has been promoted as a replacement of commonly used film-screen radiographs. Such projections can be numerically manipulated and analyzed to enhance the imaging quality, and facilitate image processing, storage and distribution. Digital imaging is particularly useful in angiography, which is the process of determining arrangement of blood or lymph vessels via injection of radio-opaque (contrast) material. By digitally subtracting the image obtained before the injection of the contrast material from the image obtained after injection, stationary overlying structures are eliminated. This enhances the presence and distribution of the x-ray contrast material in the circulation and enables the visualization of circular volumes of blood in an organ. The contrast material used is a high atomic-number substance, such as iodine, which effectively absorbers x-rays.

The basic components of a digital radiography system are an x-ray image intensifier, coupling optics, video camera tube, amplifying electronics and a video display (1). The image intensifier provides a sensor with high x-ray quantum absorption efficiency, which converts x-ray to light. The light signal is also amplified in the image intensifier to minimize the effect of noise later on in the process. The coupling optics enables the collection and transmission of photons. The video camera tube converts the optical signal to an electrical signal (current or
voltage), via a photoconductive sensing layer, a scanning electron beam readout and a load resistor. The sensing layer is essentially a two-dimensional array of pixels which is scanned by the electron beam. Each pixel is a capacitor which is charged by the electron beam and discharged by the photoelectrons due to the radiation from the scene.

The most useful application of digital radiography, as mentioned above is in intravenous angiography. This process involves the injection of contrast media (iodine) into a vein. Iodine passes through the heart and lungs before appearing in the artery of interest. As iodine passes through the body, its concentration is diluted. An x-ray radiograph obtained after the injection of iodine may still be poor and not very distinguishable from the image taken of the same organ before injection. By digitally subtracting the two images, the presence of iodine in the organ can be better observed. Image enhancement techniques, such as windowing and superline transfer functions, can further enhance the image contrast. Medical applications of digital radiography include bone abnormalities, vascular problems, atherosclerosis and cardiac flows.

Wider use of digital radiography will require overcoming the psychological hurdle of radiologists reading examinations from a video display rather than a film. Some problems in image subtraction need to be overcome, since perfect matching between pixels in two different images is difficult to achieve. More powerful image enhancement techniques need to be developed to further improve the image contrast, overcome problems at the edges, filter noise and enable size discrimination and sector localization. The use of xenon or krypton gas as contrast media for imaging in airways is also been considered by some workers. Dual energy subtraction techniques appear to be promising, but need further development. In this techniques a higher energy x-ray source is utilized, in addition to the lower energy source. High-energy photons are attenuated mainly by the high density bones, thus enabling differentiation between bones and soft tissue. Dual bone and soft tissue subtraction becomes then possible. Such technique is proved to be useful, for example, in the visualization of low doses of oral iodinated contrast media to image the gallbladder.

COMPUTER TOMOGRAPHY

X-ray computer tomography (CT) is the most mature and best known medical imaging method. It utilizes x-ray transmission measurements obtained from many angles throughout the body using a scanning mechanism. Measurements are mathematically processed by a computer to reconstruct a two-dimensional distribution of x-ray densities (attenuation coefficients) in the irradiated cross section. A three-dimensional image is obtained by combining the images of adjacent cross-sectional slices.
A CT system consists of a rotating gantry, subject table, x-ray source assembly, detector assembly, computer system and display and analysis council (2). The gantry supports the x-ray source and detectors. The table or "couch" is designed to subject the patient to the CT scanner. The x-ray source assembly includes collimators to define the incident beams. It also contains the source power supply and cooling system. The detector assembly is equipped with collimators corresponding to those used in the source assembly. Three types of detectors are commonly used: scintillators (sodium iodide and bismuth germanate), gas detectors and solid state (cesium iodide/photodiode) detectors. The electronic signal after amplification is converted to a digital signal by an analog-digital converter. The computer contains the image reconstruction software. The computerized display console of a CT scan provides a wide variety of operator-interactive image manipulation and measurement capabilities.

X-ray CT is used in a wide variety of clinical applications. Central nervous system disorders, spinal cord problems, abdominal masses and infection and soft tissue tumours are among some of the diseases diagnosed by CT imaging.

It should be emphasize her that what CT scanning provides is an image of the attenuation coefficient of the tissue and not actually the density of the material. The value of attenuation coefficients can however be related empirically to the type of tissue. The CT number are defined as the difference between the attenuation coefficient of the tissue and that of water, normalized to the attenuation coefficient of water and multiplied by a magnification factor typically equal to 1000. The CT number for water is therefore equal to zero, while that of hard bone is about 4000 and that of air is -4000.

Although the CT technology is mature and well established, there is still room for improvement. Fast scanners for imaging moving organs and circulating systems are needed. Three-dimensional scanners and dynamic spatial reconstructors are expected to emerge in the not very far future. Methods for reducing dose exposure to the patient and obtaining partial imaging of a section or a volume need also to be developed. Bayesian techniques which take advantage of previous imaging and a priori knowledge of the section to be imaged should be considered as means of reducing radiation exposure. Small and non-expensive systems for veterinarian use are also needed.

EMISSION TOMOGRAPHY

Emission tomography relies on the determination of the spatial distribution of radioactivity from radionuclides injected into the body. Emitted radiation is measured either by directly monitoring single emitted photons or of positrons emitted in coincidence. The emitted radiation is measured at different
angles around the object. Two-dimensional images of biochemical or metabolic processes are mathematically reconstructed with the aid of a computer, after corrected for the effect of radiation attenuation.

**Single Photon Emission-Computed Tomography**

In single photon emission-computed tomography (SPECT), technetium-99 is used in abdominal and head scanning, while thallium-202 is employed for thoracic scans (heart and lungs). Future development in SPECT will be most likely focused on the development of new radiopharmaceuticals for measuring metabolic functions in brain and heart. Longitudinal SPECT images are usually obtained using a multiple pinhole collimator attached to a gamma camera (3). A gamma camera is a standard scintillation device for measuring the spatial distribution of gamma sources. The multi-pinhole approach requires no camera motion and therefore no complex and costly rotating gantry system.

Medical applications of SPECT include diagnosis of bone cancer, liver and gallbladder disease, brain lesions and myocardial infarction. The development of faster scans will enable better monitoring of metabolic and biochemical processes. Work is also needed to improve sensitivity and account more accurately for attenuation effects.

**Positron Emission Tomography**

Positron emission tomography (PET) is a transverse imaging technique which yields an image of the distribution of positron emitting radionuclides injected into the body. Among the positron sources used are carbon-11 (20 min), nitrogen-13 (10 min), oxygen-15 (2 min) and Fluorine-18 (110 min); the number in brackets is the half-life of the isotope. The short half-lives of these radionuclides limit the application of PET to medical centres in the vicinity of an isotope producing facility (a nuclear reactor).

A PET system consists of a gantry containing a number of scintillation detectors operating in coincidence to provide a series of integral lines from which projections are acquired (4). The collected measurements are directed, after proper amplification, to a computer for image reconstruction and subsequent display. Correction for the attenuation of the emitted positron as they travel through the tissue is accounted for in the image reconstruction process, so that a faithful reconstruction of the distribution of radioactivity is obtained.

PET has been employed for examining metabolic processes, brain glucose activity, brain tumours and myocardial ischemia. The imaging process is however costly and complex, and it will most
likely be confined to large medical centres. Future work will perhaps focus on taking advantage of modern detectors and electronics to improve the image quality. Time-of-flight positron emission tomography is also emerging as a powerful imaging method. This technique takes advantage of fast detectors and electronics to measure the difference between the time of arrival of two annihilation photons (which is in the order of a few nanoseconds), and utilize this information for placing the annihilation event along the coincidence line. The incorporation of this information in the image reconstruction process can appreciably increase the signal-to-noise ratio, and hence improve the quality of the image.

COMPTON SCATTER IMAGING

Compton scattering can be utilized to provide images of the electron density of sections in the body. This density information is particularly useful for radiotherapy planning, where the tissue attenuation information obtained by the low energy x-ray CT is not directly applicable in planning for high energy treatment of cancerous tumours. Compton scattering is also useful for imaging central tissue surrounded by bones, where the radiation attenuation caused by the bones deteriorates the images obtained by x-ray attenuation techniques, such as CT. Moreover, Compton scattering has the potential of enabling passive imaging of tumours during radiotherapy, by simply gathering information from the photons scattered off the tumour and subsequently reconstructing the image.

Both the energy and intensity of photons scattered in an object illuminated with gamma radiation can be utilized to produce an electron density map (5). By employing a wide field-of-view detectors with high energy resolution, and relating the energy to angle of scattering, a large number of measurements can be obtained using a small number of detectors. The technique is currently being developed by this author and co-workers, taking advantage of the recent development in detector and computer technology. Less sophisticated designs of Compton scatter imaging systems has been developed by a number of workers, as shown in reference (5). These systems utilized however cumbersome methods for correcting for the attenuation of the scattered radiation as it travels through the tissue in its way towards the detector. This necessitated the use of multiple radiation exposures, which resulted in unnecessary high radiation exposure. The utilization of nonlinear mathematical algorithms developed by the author and co-workers can however alleviate this problems and enable wider use of this imaging technique. Moreover, patients undergoing radiotherapy are exposed to a large radiation dose which should result in high quality images.
REFERENCES


SESSION 8

INTERNATIONAL COOPERATION
IN OPERATIONS

SESSION CHAIRMAN

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Experience in Operation of WANO

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World Association of Nuclear Operators

The formation of the World Association of Nuclear Operators (WANO) was spurred by the 1986 accident at Chernobyl. This event made nuclear operators aware of the need for international cooperation and exchange of information and created a determination among nuclear utilities throughout the world to work together in a way that crosses all political and cultural boundaries.

This self-mandated drive for improvement was a recognition of the fact that regulations alone cannot guarantee safety. As the U.S. President's Commission on the accident at Three Mile Island Nuclear Station (the Kemeny Commission) pointed out, more regulations do not mean more safety. The ultimate responsibility for safe operation rests with the nuclear utility. In forming WANO, nuclear utility organizations affirmed their commitment to meet that responsibility and search for ways to improve nuclear plant safety and reliability.

Following the Chernobyl accident, the International Participant Advisory Committee of the Institute of Nuclear Power Operations (INPO) examined alternatives for improving cooperation and information exchange among nuclear utilities worldwide. The work of this committee ultimately led to a global commitment to establish WANO:

* The committee recommended a meeting of senior executives from nuclear operating organizations worldwide be held to address methods of enhancing cooperation among nuclear operating organizations.

* A planning committee, with international representation, organized the International Nuclear Utility Executive Meeting held in Paris in October 1987. INPO and International Union of Producers and Distributors of Electric Energy (UNIPEDE) co-sponsored the meeting.

* The 130 executives at the Paris meeting, representing 29 of the 32 countries having nuclear power programs at that time, unanimously resolved to establish a world association which subsequently became known as WANO.
Key points of the Paris resolution were as follows:

- A world association to strengthen existing links and cooperation among nuclear operators would be established.

- The mission of WANO would be to maximize the safety and reliability of the operation of nuclear power plants by exchanging information, and encouraging communication, comparison, and emulation amongst its members.

- The mission would be accomplished through four regions with centers in Atlanta, Moscow, Paris, and Tokyo, and a coordinating center in London.

- The WANO Coordinating Center would work closely with the International Atomic Energy Agency (IAEA) to ensure no unnecessary duplication of effort.

- A Steering Committee would be established to set up WANO.

The Steering Committee was subsequently formed under the leadership of Lord Marshall, then chairman of the Central Electricity Generating Board (CEGB) in the United Kingdom. The Steering Committee had representation from all regions, including a representative from Canada.

After a period of about 18 months during which the administrative and organizational structure of WANO was developed under the guidance of the Steering Committee, the organization was officially started in Moscow in May 1989.

On May 15 of that year, representatives of electric utilities with operating nuclear power plants gathered from around the globe. The meeting was hosted by the U.S.S.R. Ministry of Nuclear Power and Industry, and the All Union Research Institute for Nuclear Power Plant Operations (VNIIAES) and was chaired by Lord Marshall.

Utility representatives from 31 countries having nuclear power programs were invited. Some 321 participants representing 30 countries were in attendance. There was strong North American participation with representatives from all nuclear organizations in Canada, the U.S. and Mexico in attendance.

The highlight of the Inaugural Meeting was the signing of the WANO Charter by 144 representatives of nuclear operating organizations from 29 countries. One by one, they signed their names to a charter for WANO. With their signature, they made a commitment to freely exchange operating information and to use that information to improve plant safety and reliability.
The mission of WANO is clear: To maximize the safety and reliability of the operation of nuclear power plants by exchanging information and encouraging communication, comparison and emulation among its members.

Communication, comparison and emulation, the nuclear industry has found, are powerful tools in building a record of safety and reliability. WANO serves as a worldwide facilitator for these activities, representing organizations operating more than 400 nuclear units throughout the world.

WANO operates through its four regional centers in Atlanta, Moscow, Paris and Tokyo. Each utility organization is a member of one or more of these regional centers, with staffing provided by the region's members. While usually guided by geography, a utility may choose the center to which it belongs.

A small coordinating center based in London coordinates the activities of the regional centers. It also works closely with the International Atomic Energy Agency and other international organizations to eliminate duplication of effort. To ensure that WANO could operate promptly after its inaugural meeting, each regional center began interim operation in advance of the WANO inauguration.

Since the inaugural meeting, WANO and its centers have become fully operational. I should add that WANO's membership includes nuclear operating organizations in every country with a nuclear power program. Atlanta Center members include the nuclear utilities in Brazil, Canada, Mexico, the United States and Yugoslavia -- and effective January 1, 1992 -- Romania.

The regional centers are linked to one another, to their individual members and to the coordinating center by an electronic communications system. This computer-based system allows information exchange on a wide range of topics related to operational safety and reliability.

The organizational structure is specified by the WANO Charter and the WANO Articles and Memorandum of Association. Highlights of the WANO organizational structure are as follows:

- The structure of WANO consists of a general assembly of all member organizations, a governing board, a coordinating center, and four regional centers.

- All nuclear operating organizations belong to one of the four regional centers.

- Each regional center has its own governing board. The regional center governing board appoints a director for the center.
Overall WANO direction is provided by the WANO Governing Board. This board consists of two members from each region; the chairman of the regional governing board and one member appointed by the governing board of the region. A WANO Governing Board chairman is selected by the board members.

The WANO Coordinating Center, located in London, has a small permanent staff plus a seconded engineer from each regional center.

Each regional center also has a small permanent staff and generally a seconded engineer from each member.

The work of WANO involves four principal programs implemented and operating on a worldwide basis. They are:

- Exchange of operating experience
- Exchange of good practices
- Exchanges between operators, and
- Collection and distribution of performance indicator data

Additionally, the WANO Moscow and Paris Centers have formed a temporary special project to suggest improvements for Soviet-designed pressurized water reactors (VVER). I will speak more on this later.

First, through the Operating Experience Information Exchange Program, data relevant to safe plant operations is collected, screened, analyzed and distributed. Reports are prepared and disseminated on significant nuclear plant events, based on consistent event selection criteria.

Three types of reports are prepared. The first, an event notification report, is an early notification report for alerting other utilities to what has occurred so that they may understand the event and initiate a determination of their susceptibility to a similar occurrence at their plants.

The second report, an event analysis report, provides a detailed description of an event and its underlying causes so that utilities can understand the importance, consequences, and lessons learned from the event; determine the applicability to their design and operating practices; and take actions to prevent similar occurrences.

The third type of report was not part of the original Operating Experience Exchange Program. The Event Topic Report (ETR) was a later development born of the need to develop operating experience reports that cover topics rather specific events. In many cases, several similar events form the basis of an ETR.
The WANO event reports are prepared by the member organizations and transmitted to their regional center. The center then reviews the report for clarity and completeness, makes necessary revisions and distributes the report to all WANO members. As of the end of 1991, over 600 event reports had been distributed since the program began operation in 1989.

The second major area is the exchange of good practices. The WANO good practices program encourages the identification and distribution of effective techniques or practices used by a WANO member in the operation of their nuclear plants.

Such good practices are intended to assist other WANO members in effectively managing and operating their plants. Good practices, when identified, are distributed to all members of the region issuing the document, the other regional centers, and the Coordinating Center.

The third area is exchanges between operators. The WANO operator-to-operator program includes the exchange of information by visits between nuclear power plants, workshops and seminars, and the exchange of staff personnel for the purpose of learning and emulating the industry's best practices.

Since the beginning of WANO, over 100 exchange visits have been conducted from one nuclear plant to another. As a special sub-task of this program, the WANO Governing Board established at the Moscow Inaugural Meeting an objective to complete reciprocal exchange visits between each of the 24 plant sites belonging to the Moscow Center and a plant belonging to one of the other three regions.

The objective of this sub-task was to afford the opportunity for the managers of the former Soviet bloc plants to understand approaches to the management and operation of nuclear plants in other parts of the world and to lay the foundation for the future exchange of operating experience information with the Moscow Center plants.

WANO-Atlanta Center member plants participated in 24 of these 48 initial exchange visits with the Moscow Center plants. One of these exchanges was between the Juragua plant in Cuba (a member of the Moscow Center) and the Laguna Verde plant in Mexico (a member of the Atlanta Center).

Subsequent to the initial 24 visits between Atlanta Center and Moscow Center plants, there have been follow-up visits between some of the original participants as well as additional visits by other Atlanta Center members not involved in the initial visits. In addition to the Moscow Center exchange visits, Atlanta Center members have visited and hosted plants in the other two regions. Exchange visit activity by Atlanta Center members has leveled off at about 20 visits per year.
The fourth area of focus is the collection and distribution of performance indicator data. WANO members report data on 10 key performance indicators, which were based on the Institute of Nuclear Power Operations (INPO) indicators used by U.S. utilities since 1985 and work done by the International Union of Producers and Distributors of Electricity (UNIPED).

In 1989, this set of ten plant performance indicators was adopted by WANO to provide a quantitative indication of nuclear plant performance in the areas of nuclear plant safety and reliability, plant efficiency, and personnel safety.

The WANO indicators are intended principally for use by nuclear operating organizations to monitor performance and progress, to set challenging goals for improvement, to gain additional perspectives on performance relative to that of other plants, and to provide an indication of the possible need to adjust priorities and resources to achieve improved overall performance.

WANO performance indicator data is provided quarterly by nuclear plants to their respective regional center and then stored for processing in a central computer data base located at the Atlanta Center. An annual performance indicator report displaying worldwide histograms of the indicator values for individual nuclear units, member annual comparisons, and worldwide trend graphs is provided to WANO members. Members use the data to compare the performance of their units with those of similar design and to monitor the industry's collective progress. The initial performance indicator report for 1990 was distributed in May of 1991, and the second report for 1991 was issued last month. At present, WANO performance indicator data is being reported by over 96 percent of the nuclear stations in the world.

The WANO performance indicators are intended to support the exchange of operating experience information and allow consistent comparisons of nuclear plant performance. It is expected that WANO performance indicators will encourage emulation of the best industry performance and further motivate the identification and exchange of good practices in nuclear plant operations.

In addition to these four major areas, the WANO Moscow and Paris Centers have formed a temporary special project to suggest improvements for early model Soviet-designed pressurized water reactors (VVER).

This project was established in 1990 to assist in improving the safety of the Soviet-design VVER 440 model 230 reactors, located in Eastern Europe and the Soviet Union. The purpose of the project is to identify areas where assistance by Western utilities would be helpful in defining a modernization program for this type of plant.
As an adjunct to this special project, WANO is assisting in the efforts of the international community to upgrade the operational safety of the Kozloduy Nuclear Power Plant in Bulgaria. Assistance is taking two forms. One involves the twinning of the Kozloduy plant with a French plant, the Bugey nuclear power plant. This effort is coordinated by Electricité de France with support by personnel from the Greifswald plant in Germany. The twinning approach involves active, long-term exchange of information between the two plants and includes exchange of technical staff. Since July of 1991, full-time engineers from Bugey have been working with the Kozloduy staff.

The second area of assistance involves helping the Kozloduy staff return the plant to the condition it was in just after commissioning. This outage assistance program is intended to help ensure all plant systems work according to the original plant design. Currently, 12 engineers -- including one from the WANO-Atlanta Center -- are working at Kozloduy. In addition, spare parts from the shutdown VVER 440 model 230 units at Greifswald are earmarked for use at Kozloduy.

The future of WANO looks promising. As specified by the WANO Charter, biennial general assembly meetings are held to review activities and progress for the members, to gain guidance from members for future activities, and to elect a new president. The first biennial general meeting following the inaugural meeting in Moscow, was hosted by the Atlanta Center on April 21-23, 1991 in Atlanta, Georgia. There were 242 executives, representing all countries having operating nuclear power plants, except Bulgaria, in attendance. There were 16 participants from the former Soviet Union, including six site directors.

Special presentations were made to the participants by U.S. Secretary of Energy James Watkins; Canadian Minister of Energy, Mines, and Resources Jake EPP; the former U.S.S.R. Deputy Minister for Nuclear Power Plant Operation Eric Pozdyshev; and IAEA Director General Hans Blix.

There was an overwhelming consensus that current WANO activities should be continued and strengthened; that WANO should widen the scope of exchange visits, and improve the collection of operational performance indicator data, the electronic exchange of information and the conduct of seminars and workshops.

Highlights of the meeting included:

* The Guangdong Nuclear Power Joint Venture Company from The Peoples Republic of China joined WANO and signed the WANO Charter.

* and Mr. Shoh Nasu, president of the Tokyo Electric Power Company, was elected as the new WANO president.
Not merely content to perpetuate existing programs, participants at the Biennial General Meeting discussed ways to make WANO more effective. One result of this discussion was the agreement to explore a voluntary WANO peer review program. As WANO's next evolutionary step, these peer reviews would entail independent, outside observation of plant operations by experienced operators from other plants with the objective of providing recommendations for improvements.

Since the Biennial General Meeting, plans have been made to conduct a series of five to seven pilot peer reviews. The Atlanta Center was given lead responsibility for this pilot project.

The first pilot peer review was conducted at the Paks Nuclear Power Plant in Hungary in February 1992. The Atlanta Center staff is working with the Coordinating Centre and the other regional centers to schedule three more pilot peer reviews in 1992. At present, pilot peer reviews are scheduled for the Koeberg plant in South Africa, in Canada, in the U.S. and in Taiwan.

While these pilot peer reviews are led and coordinated by the Atlanta Center, the peer review teams include members of the other three regions.

Our experience from the pilot peer reviews will then be applied to subsequent peer review programs in each region. It is envisioned that each region will be responsible for organizing and managing its own peer reviews. However, extensive use of personnel from other regions and standardized methodologies will be encouraged.

In summary, the formation of WANO was a timely response to the need for cooperation and exchange of information within the international nuclear community. We have been successful in establishing relationships that will enable WANO to be a catalyst for improvement at the world's nuclear power plants.

This includes new plants as well as those that have been in operation for several years. The commitment shown by the world's nuclear operators to the mission of WANO has been impressive. The years to come will demonstrate just how much this spirit can achieve to further enhance safety and reliability on a global scale.

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1. BACKGROUND

The CANDU nuclear electric generating station is the product of an indigenous nuclear industry. The commercial viability of the CANDU design was established by the Ontario Hydro Pickering reactors in the early 1970's. Subsequently, CANDU commercially sized nuclear stations were constructed and are operated in the provinces of Ontario, Quebec and New Brunswick in Canada, and in Pakistan, India, Korea and Argentina. Further CANDU units are being constructed at present in Romania. Table 1 presents a listing of CANDU stations now in operation or being constructed. Similar to the operators of other reactor types, the Canadian operators of CANDU nuclear stations realized that close cooperation and mutual assistance between them would help to share the costs of support required for the CANDU reactor concept. In particular, the sharing of experiences and solutions to design and operating problems would help to head off potential incidents by allowing proactive action to be taken based on the experience of others.

<table>
<thead>
<tr>
<th>Station</th>
<th>Location</th>
<th>Size (MWe)</th>
<th>First Unit In-Service</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pickering</td>
<td>Canada</td>
<td>4 x 500</td>
<td>1970</td>
</tr>
<tr>
<td>Bruce NGS A</td>
<td>Canada</td>
<td>4 x 900</td>
<td>1976</td>
</tr>
<tr>
<td>Pickering NGS B</td>
<td>Canada</td>
<td>4 x 500</td>
<td>1980</td>
</tr>
<tr>
<td>Bruce NGS B</td>
<td>Canada</td>
<td>4 x 900</td>
<td>1986</td>
</tr>
<tr>
<td>Darlington NGS A</td>
<td>Canada</td>
<td>4 x 900</td>
<td>1990</td>
</tr>
<tr>
<td>Point Lepreau</td>
<td>Canada</td>
<td>1 x 600</td>
<td>1982</td>
</tr>
<tr>
<td>Gentilly II</td>
<td>Canada</td>
<td>1 x 600</td>
<td>1984</td>
</tr>
<tr>
<td>KANUPP</td>
<td>Pakistan</td>
<td>1 x 137</td>
<td>1967</td>
</tr>
<tr>
<td>RAPP</td>
<td>India</td>
<td>2 x 220</td>
<td>1973</td>
</tr>
<tr>
<td>Embalse</td>
<td>Argentina</td>
<td>1 x 600</td>
<td>1985</td>
</tr>
<tr>
<td>Wolsong 1</td>
<td>S. Korea</td>
<td>1 x 600</td>
<td>1985</td>
</tr>
<tr>
<td>Cernavoda</td>
<td>Romania</td>
<td>5 x 600</td>
<td>1994*</td>
</tr>
</tbody>
</table>

*Under Construction

Consequently, the three Canadian utilities in Ontario, Quebec and New Brunswick, and the CANDU reactor designer, Atomic Energy of Canada Limited, established the CANDU OWNERS' GROUP (COG) in 1984, with 1985 being the first full year of operation. This
association of utilities and AECL was formed to provide a framework to promote closer co-operation among the utilities owning and operating CANDU stations in matters relating to plant operation and maintenance and to foster co-operative development programs leading to improved plant performance. The specific objectives adopted are:

- to facilitate an exchange of information among CANDU station owners and operators,
- to provide a basis for mutual assistance, and
- to establish a forum for the planning and funding of generic programs.

In order to meet these objectives COG established Cooperative programs in three areas:

- Information Exchange
- Project Coordination
- Research and Development

To undertake and administer these joint programs, a full-time COG Operations office was established. Ontario Hydro provides the management of the COG Operations office with staff assigned from the COG members. This office reports to a Directing Committee comprised of two senior representatives from each of the founding member organizations. The directing Committee is responsible for overall direction of COG and for approval of policies, programs, and associated funding. The current COG operating structure is illustrated in Figure 1.

Since being established in 1984, the activities of the CANDU Owners' Group have expanded in a number of areas. For example, participation in the COG information exchange program has expanded to include the owners and operators of all CANDU stations in operation or under construction worldwide. Both the dollar value and scope of the research and development program administered by COG has increased substantially as well as its expansion into a wider range of R&D program areas. In 1986, on behalf of the Canadian CANDU owning utilities, COG joined the Institute of Nuclear Power Operators (INPO). Also in 1989, the Canadian CANDU utilities joined the World Association of Nuclear Operators (WANO) with COG acting as the point of contact for Canada.

2. INFORMATION EXCHANGE PROGRAM

The COG information exchange program was one of the first activities to be established by COG in 1985. At that time, the four founding COG members were the only participants in the program. Since then the information exchange program has expanded to include all owners and operators of CANDU station worldwide. The Comision Nacional de Energia Atomica (CNEA) of Argentina and the Korean Electric Power Corporation (KEPCO) of Korea joined the information exchange program in 1986; the Pakistan Atomic Energy Commission (PAEC) of Pakistan and the Nuclear Power Corporation
(NPC) of India joined in 1987; and, the Regis Autom de Electricalitat (RENEEL) of Romania joined in 1992.

The Information Exchange Program nurtures the sharing of pertinent and timely information amongst the members participating in the program. The COG information exchange program is based on an electronic messaging system called CANNET. The electronic messaging system (CANNET) provides a direct link between the technical staff at each of the CANDU stations as well as direct and immediate access to CANDU designers. CANNET provides the means for discussion between station technical staff on a day-to-day basis, bringing their collective operating experience to bear on operating problems.

The computerized databases provide access to over 30,000 reports related to CANDU station operation and maintenance. Reports are collected from all of the CANDU stations, CANDU designers, and CANDU related research programs. They are screened for significance, summarized, coded by COG staff and posted on CANNET. Database searches are provided by COG on request.

The CANNET system also has interfaces with the INPO and WANO information exchange programs, and relevant information from these two areas is reviewed by COG Operations staff and posted on CANNET bulletin boards if appropriate. The CANDU information exchange network is shown on Figure 2.

Since its inception in 1985, the information exchange program has continued to grow as the participants gain confidence in the value of the service provided by the COG office. This growth is shown on Figures 3 and 4. In Figure 3, Significant Events are those incidents at nuclear stations that are reported to the national regulatory authority. External Events are those events occurring at non-CANDU stations that are considered to have specific relevance to CANDU stations. Proposed Changes are approved modifications proposed by station operating staff to improve safety, reliability, operability or economics.

In addition to the electronic exchange of information, the COG Operations office issues newsletters and bulletins and organizes conferences on topics of interest to its members. All of this is aimed at improving communication and co-operation and sharing station experience amongst the CANDU owning organizations worldwide. By this sharing, experience has shown that benefits can be realized in terms of economics, availability, and reduced radiation exposure of station staff. It is also conceivable that timely sharing of information can lead to proactive action and perhaps avoid nuclear safety related incidents.

3. PROJECT COORDINATION

The CANDU Owners' Group provides a means whereby COG members can identify common needs and opportunities related to plant
operation and maintenance, can define shared-cost programs for collective action to resolve common needs, and can pursue common opportunities. The Projects Coordination unit is the vehicle in COG to establish and administer such programs.

A tabulation of some of the current projects is provided in Table 2. These joint efforts have the benefit of enhancing economics and safe performance of CANDU stations through the sharing of cost, experience and expertise within the CANDU industry. Sharing of expertise is particularly important in those technical areas that are unique to CANDU such as fuel channel inspection and reactor core components. The Projects coordination program also provides a focal point where suggestions for common approaches, such as emergency preparedness, can be tabled for discussion.

Table 2
Joint Projects

| Emergency Preparedness |
| Environmental qualification |
| NMAC membership |
| Eddy current inspection verification |
| Seismic instrumentation |
| Joint component procurement |
| - flux detectors |
| - liquid zone control units |
| - computer spare parts |
| - I&C Amplifiers |
| Component reliability database |
| Steam generator cleaning |
| Reactor building leak monitoring |
| Construction tooling |
| Fuel channel inspection tooling |
| Spacer location and relocation tooling |
| Single fuel channel removal tooling |
| KANUPP reactor core integrity assessment |

In 1990, in conjunction with the Canadian government, COG contracted with the International Atomic Energy Agency (IAEA) for a preliminary assessment of the KANUPP station in Pakistan. This assessment concentrated on determining the activities that would be necessary to evaluate the status of the pressure tubes in the reactor to determine their fitness for continued operation based on Canadian experience.

COG is currently in the process of assisting Pakistan with arranging for contracts to perform the needed evaluation. A similar request from India is being explored.

These joint efforts have the benefit of enhancing economics and safe performance of CANDU stations through the sharing of cost, experience, and expertise within the CANDU industry.
4. RESEARCH AND DEVELOPMENT

In 1985 a shared-cost research and development program was established under the auspices of the CANDU Owners' Group. This development was an extension of a prior development program (known as CANDEV) that was cost-shared by Atomic Energy of Canada Limited (AECL) and Ontario Hydro. The 1985 COG program, however, included the other two Canadian CANDU owning utilities as well as Ontario Hydro and AECL. Provision was also made for participation of other CANDU owners and non-CANDU owners in the R&D program with CNEA of Argentina being the first non-Canadian direct participant. Since the inception of the program in 1985, COG has negotiated cooperative R&D agreements with ten organizations in eight different countries.

The objective of the Research and Development (R&D) program is to maintain, and where applicable, improve the licenseability, safety, reliability, and technology of CANDU PHWR, and to develop the necessary technology for the eventual disposal of used nuclear fuel.

In 1986 the COG research and development program of approximately $15 million (Canadian) was concentrated in the technical areas of reactor components, safety and licensing and CANDEJ technology. Over the years the COG R&D program has grown substantially in funding level to approximately $180 million (Canadian) in 1992 and is concentrated in the technical areas of Fuel Channels, Safety and Licensing, CANDU Technology, Nuclear Waste Management, and Health and Safety.

The individual research and development projects that make up the overall program are established by means of a tiered system of committees guided by a full-time Program Manager from COG Operations for each of the technical areas in the program. A number of working parties for each main technical area is established. Membership on these working parties consists of appropriate representatives from research, design and operating units of the funding organizations. The working parties develop research and development proposals in their areas of expertise and set priorities for the individual work items. It is at this stage of formulating the program that the users of the output from the research and development activities can exert their influence.

The working parties present their proposals and priorities to a Technical Committee in each main technical area of the program. The Technical Committees have senior technical managers from the participating utilities and AECL, and the committees further reprioritize the work projects and recommend to the COG Directing Committee the split of work among the main technical areas. The chairman of the Technical Committee is the full-time COG Program Manager responsible for the particular technical area.

The COG Directing Committee reviews and modifies or approves the
recommendations from the Technical Committees and provides any top-down strategic direction deemed necessary. This top-down strategic direction is provided via a strategic planning process that culminates annually in an R&D Business Plan covering a 10 year strategic horizon and a 3 - 5 year technical plan. The above description of the tiered structure for administering the COG research and development program is shown in Figure 5, and the growth of the program in each technical area is listed in Table 3.

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>Fuel Channels</td>
<td>3</td>
<td>3</td>
<td>21</td>
<td>34</td>
<td>36</td>
<td>34</td>
<td>39</td>
</tr>
<tr>
<td>Safety &amp; Licensing</td>
<td>11</td>
<td>14</td>
<td>15</td>
<td>22</td>
<td>19</td>
<td>30</td>
<td>40</td>
</tr>
<tr>
<td>CANDU Technology</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>7</td>
<td>10</td>
<td>17</td>
</tr>
<tr>
<td>Health &amp; Safety</td>
<td>5</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear Waste Magm’t</td>
<td>25</td>
<td>26</td>
<td>27</td>
<td>34</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility Support</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>21</td>
<td>28</td>
</tr>
</tbody>
</table>

Using the organizational structure described above, the COG Operations office provides the administration and integration of the technical and financial support for the Canadian national nuclear research and development program to meet the needs of operating CANDU stations. The research and development activities are mainly performed at the laboratories of AECL-Research at Chalk River in Ontario and Whiteshell in Manitoba with complementary projects being undertaken at Ontario Hydro laboratories and other commercial, provincial, and university research facilities. The breakdown of COG research and development expenditures by contractor is shown on Figure 6.

The funding for the 1991 COG research and development program is provided by AECL-Research (50 per cent); Ontario Hydro (40 per cent); New Brunswick Electric Power Commission (5 per cent); and Quebec-Hydro (5 per cent). A small amount of funding for the 1991 program is provided by CNEA in Argentina. The breakdown of COG research and development expenditures by R&D technical area is shown on Figure 7.

The Fuel Channel research and development program administered by COG focuses its efforts on improving services to the utilities for inspection and maintenance related to fuel channels and on conducting research to enable prediction of long-term behaviour of pressure tubes in CANDU reactors. The results
of the fuel channel research and development program have been used to produce Fitness-for-Service guidelines for CANDU pressure tubes in operating reactors. These guidelines will be used in evaluating the condition of the pressure tubes in the KANUPP reactor in Pakistan on behalf of the IAEA.

On another international front, agreements between Canada and the USSR have allowed for the exchange of technical information and exchange visits related to pressure tube materials. Such exchange of information and experience should help to obtain a broader understanding of CANDU reactor operation and contribute to the avoidance of pressure tube failure incidents such as occurred at Pickering "A" Nuclear Generating Station in 1983.

The COG Safety and Licensing research and development program has the objective of improving the understanding of the processes underlying reactor safety and of the operating safety envelope of CANDU reactor systems. The results of the safety and licensing research program are used to develop and verify the analytical methods used for the assessment of the consequences of postulated accidents in CANDU nuclear generating stations. The program maintains links to international programs through participation in committees such as the IAEA Thermal Reactor Safety Research Technical Committee and through participation in international joint programs of interest to COG members. For example, COG is participating in joint programs with CEA in France, BMFT and KfK in Germany, HBC in Belgium, HALDEN in Norway, USNRC in the United States, and NUPEC in Japan. Obtaining this information through joint funding of programs avoids duplication of efforts and creates a broader understanding of the phenomena involved in predicting the consequences of postulated accidents.

The CANDU Technology research and development program is focused on the maintenance and improvement of the performance of operating CANDU stations. Particular emphasis is placed on development of out-reactor components and processes that are unique to CANDU. Information from the research and development program is used by all participants to the program to improve operating performance and to reduce loss of production from CANDU generating stations. Again, as in the Safety and Licensing Program, COG is participating in international joint programs to minimize duplication of effort, specifically with EPRI and NMAC of the United States.

The COG Waste Management research and development program is mainly a program to develop and assess the Canadian concept for the disposal of high level nuclear fuel waste. The program is a joint one between AECL-Research and Ontario Hydro with most of the work being done at the Whiteshell Nuclear Laboratories of AECL-Research. The disposal concept being developed is one in which the nuclear fuel waste is disposed of in an underground vault in the plutonic rock of the Canadian Shield. As in the
other research and development program areas, the information obtained from the program is shared via joint information sharing agreements between Canada and other countries such as Sweden and the United States.

This co-operative program should help to provide information and understanding in an area that is of concern to many people.

The Health and Safety research and development program has the objective of improving the understanding of the effects of radioactive materials on humans and their environment. It is a joint program of the Canadian utilities and AECL-Research, which will support the assessments of the health impacts of the operation of CANDU nuclear generating stations, and in this way should contribute to the health and well-being of those living in the vicinity of nuclear generating stations.

The overall COG research and development program is an example of where organizations can pool their resources effectively to obtain information that should assist in improving the economic, reliability, and safe performance of CANDU nuclear generating stations. By means of entering into joint agreements with international organizations, the results of the COG research and development program may be exchanged for the beneficial use of other countries.

5. INTERNATIONAL PARTICIPATION

As discussed throughout the previous sections of this paper, the CANDU Owners' Group has a number of international links that allow for the dissemination and exchange of information and experiences that could be of benefit to many utilities. The international links include the connections of the CANDU information exchange system with INPO and WANO, the association with the IAEA to provide assistance in the safety evaluation of the KANUPP station, and the many agreements for exchange of research and development information and joint participation between COG and organizations in other countries.

Not the least of these international links are the ones with the CANDU station operating utilities in Argentina, Korea, India, Pakistan, and Romania. All of these links should help improve the economics, reliability, environment impact, and safety of the operation of CANDU nuclear stations world-wide.

6. FUTURE FOCUS

The benefits of a strong CANDU industry alliance is particularly significant given the relatively small base of CANDU expertise (with respect to Light Water Reactor expertise). To sustain a
viable nuclear program based on the CANDU reactor, there is a need for a coordinated effort that will ensure effective and efficient use of the resources that are available. Free exchange of information, consolidation of expertise, sharing of costs, and co-operative effort are all paramount to sustaining the CANDU reactor system. COG provides a focal point for these ideals and is committed to fostering the concept of co-operation and partnership as a means of strengthening the CANDU system. "Strength through Co-operation" will continue to be the focus of COG activities throughout the 1990s.

SUMMARY

The CANDU Owners’ Group (COG) was established in 1984 to provide a framework for co-operation, mutual assistance, and exchange of information to support the development, operation, maintenance, and economics of CANDU nuclear generating stations. COG was formed by the three Canadian utilities operating CANDU nuclear stations and Atomic Energy of Canada Limited (AECL), the corporation having the overall Canadian mandate for the development and application of nuclear energy. Since its formation, COG has expanded internationally to include participation by the utilities with operating CANDU nuclear stations in Korea, Argentina, India, Pakistan and Romania.

A full-time Manager of COG Operations, with a staff of approximately twenty-six, provides day-to-day administration of the three COG programs in the areas of Information Exchange, Project Coordination, and Research and Development. A Directing Committee composed of two members from each of the founding partners provides direction to the Manager of COG Operations. A tiered committee structure is used to plan and provide advice to the COG Directing Committee on the $180 million (Canadian) COG research and development program. Through these organizational arrangements and program areas, COG has shown itself to be a viable concept for strengthening the CANDU program.

COG has established a number of international links, including the formal Canadian interface with INPO and WANO, a number of international agreements for the exchange of technical information, and an association with the IAEA for establishing a program to evaluate the condition of the CANDU generating station KANUPP in Pakistan.

The sharing of expertise, resources, experiences, and information in areas of common interest through participation in COG programs will help to ensure that operators of CANDU stations world-wide can provide electricity for their customers with improved economics, reliability, environmental impact, and safety. There are numerous examples of the benefits realized from participation in the co-operative venture called the CANDU OWNERS’ GROUP.
FIGURE 1
FIGURE 4

Number of Accesses (Thousands)

1985
1986
1987
1988
1989
1990
FIGURE 6

AECL 90%

Ontario Hydro 6%

Others 4%
Waste Management 23%

Fuel Channels 23%

Safety & Licensing 23%

Health & Safety 4%

CANDU Technology 10%

Facility Support 16%
THE IAEA OPERATIONS ASSISTANCE PROGRAMME

E.M. Yaremy
Division of Nuclear Safety
International Atomic Energy Agency (IAEA)
Vienna, Austria

1.0 INTRODUCTION

There are currently 420 NPPs in operation in 26 countries and 77 under construction. Cuba and Romania are scheduled to complete their first units in the next few years.

Globally, nuclear electricity represents about 17% of total electricity generation. In 1990 the share in different countries differed considerably, reaching some 75% in France, 60% in Belgium and about 50% in Hungary and the Republic of Korea.

While western Europe has the largest number of units in operation, eastern Europe has the largest number under construction. An overview of plants in operation and under construction by region is presented in Figs 1 and 2.

2.0 IAEA OPERATIONAL SERVICES

In the past 10 years a number of international operational services have been initiated by the IAEA for the purpose of enhancing the operational safety of nuclear power plants worldwide.

The most widely known service is the Operational Safety Review (OSART) programme which began in 1982. In addition there are the Incident Reporting System (IRS) which is a joint IAEA/OECD-NEA system and the Assessment of Significant Event (ASSET) service started in 1986.

2.1 The OSART Programme (Operational Safety Review Team) Programme

Background. In the OSART programme international expert teams make in-depth three week reviews of operational safety practices at nuclear power plants. The OSART reviews offer excellent opportunities for the exchange of experience between expert team members and operating organization staff on how to enhance the safe operation of their NPPs. As of April 1992, a total of 56 OSART missions have taken place - 43 OSART missions to plants in operation and 13 Pre-OSART missions to plants under construction. In all, 50 plants in 25 countries have been visited (Table 1). In 1991, four of the OSART missions were special Safety Review Missions conducted at Soviet designed VVER-440 model 230 NPPs in Eastern Europe and Russia. These four missions combined a review
of operational safety with a review of the design of these NPPs. With the exception of four, all IAEA Member States with active nuclear power programmes have been visited at least once, some as many as four times.

**Main Features.** The primary objective of an OSART is to conduct a critical peer review of operating practices at individual NPPs and to give advice on how they could be improved from the point of view of safety. A secondary objective is to disseminate as widely as possible the good practices identified at any NPP that could be emulated elsewhere and to alert the world nuclear community to weakness that should be remedied.

It is important to note that the OSART is a peer review of operating policies, principles, practices and procedures. As such, the reviewer uses his expert knowledge, as a peer on the subject, and compares the plant's performance with his own views of what constitutes an adequate safety level. The reviewer has two goals in mind:

(a) to identify to the operating staff of the plant how and where safety improvements can or should be made;

(b) to identify good practices that should be brought to the attention of other nuclear power plant operators.

An OSART mission is not a regulatory review. It starts with the assumption that the plant meets the safety requirements of the country in question and that both the responsible operating organization and the regulatory authorities have also reached the conclusion that safety is adequate.

The standard scope of an OSART comprises eight important areas of operational safety: plant management, organization and administration; personnel training and qualification; operations; maintenance; technical support; radiation protection; chemistry; and emergency planning and preparedness and takes 3 weeks to conduct.

Of the 56 OSART missions to date there have been 13 Pre-OSART missions to nuclear power plants in the construction phase. The full scope of a Pre-OSART includes: project management; quality assurance; civil construction; mechanical equipment; electrical equipment; instrumentation and control; preparation for start-up; preparation for operation; training and qualification; radiation protection; and emergency planning and preparedness.

Starting in 1987, the IAEA requested that formal one-week follow-up visits be conducted at the NPPs 12 to 18 months after the OSART/Pre-OSART missions. The follow-up visits are conducted by the team leader and two or more other members of the original team. The purpose of the follow-up visit is to determine the
status of the proposals made in the original visit and to assess whether follow-up actions have been adequately discharged and/or whether progress on uncompleted actions are satisfactory. To date, 14 follow-up visits have been conducted.

Team Composition. An OSART team usually comprises 10 to 12 experienced experts each with 10 or more years nuclear experience. The desired team composition is two-third IAEA staff. The external consultants are recruited from NPPs, utilities and regulatory authorities to provide specific expertise in the subject areas and for the particular reactor type being reviewed. IAEA team members have similar nuclear experience backgrounds and are familiar with the various national practices. They ensure consistency of the reviews. Usually two or three observers from countries who are developing nuclear power programmes are attached to most OSARTs for on-the-job training. To the end of 1991, 377 external experts and 94 observers have participated in OSART missions in addition to the IAEA staff members (Table 2).

Before the actual review, the team members familiarize themselves with the main features of the plant and its activities by reading information which is provided to them in advance. On location, they study in detail plant documents and records, examine operating results, observe personnel in the preparation and execution of work, and interview supervisors and subordinates as necessary to clarify their observations. The reviews are conducted on the basis of OSART Guidelines which draw on the NUSS Codes and Guides on Operational Safety and quality assurance. More recent reference documents include a report entitled "Safety Culture" which was prepared by the International Nuclear Safety Advisory Group (INSAG) and an IAEA Technical Report entitled "Quality Management for Nuclear Power Plant Operation". The Guidelines are intended to help each expert carry out his review. They are not all inclusive and are not intended to limit the expert's investigations. Each expert is expected to use his own expertise and consult with the other team members about best international practices in order to judge whether or not the objectives of the plant's nuclear safety programme are being met.

Results. In addition to the Summary Report of the OSART the IAEA periodically publishes reports which summarize the results of OSART missions; to date four of these reports have been published.

Most of the OSART reviews confirmed that the NPPs were being operated by experienced, dedicated staff who were fully aware of their responsibilities for safety in operation. Recommendations were made at all plants visited on how to further enhance operational safety. Suggestions were also made which were aimed at improving performance. It has been found that even well-operated plants can learn from an OSART mission due to the many
years of nuclear experience embodied in the team. Many good and some unique practices were identified. The experts and observers, in addition to providing their expertise, learned from their participation in the OSART reviews. All plants reviewed were responsive to the OSART recommendations and suggestions. Corrective actions were initiated quickly.

The four Special Safety Review Missions to the Soviet designed VVER-440/230 NPPs in 1991 noted significant differences in operating practices compared to international practices since their operators had been isolated from the rest of the nuclear safety community until recently.

2.2 The IRS (Incident Reporting System) Programme

The IRS is an international focal point for NPP operating experience derived from unusual events. The IRS has been established by the IAEA and the OECD/NEA for the exchange of operating experience on an international level, for one country to benefit from the experience gained in other countries. It is intended that such exchange should take place whenever analysis by a country of its operating experience identifies a lesson to be learned to avoid a repetition elsewhere. Under these circumstances regulatory body-oriented IRS should be considered as an element of international obligations in nuclear safety.

Today the more than a thousand NPP unusual events in the IRS contain considerably more lessons learned for the international operating experience feedback process. The two-fold process of the IRS analyses includes national investigation of unusual events in NPPs with subsequent in-depth discussion and analysis of event populations by international experts. Results of international analysis activity of the IRS are distributed by means of topical safety studies, reviews on patterns and trends in NPP events, reviews of experience on root cause analysis of incidents and annual reports.

We, at the Agency, want to (1) improve speed and efficiency of communication of evaluated information on NPP unusual events; (2) to increase the value of IRS information in the operating experience feedback process; (3) to enhance capability of countries for systematic analysis of NPP operating experience; (4) to identify national weak points of operating experience feedback domain; (5) to make IRS activity more transparent and more visible for the public.

2.3 The ASSET (Assessment of Safety Significant Events Team) Programme

The ASSET Services. Since 1986, the IAEA has been conducting ASSET missions in various countries that operate nuclear power plants. The ASSET programme is an increasingly well known IAEA
activity in the nuclear community: 3 missions in 1989, 8 ASSET missions requested in 1990, 11 missions in 1991, 19 missions in 1992 including PWR's, PHWR's, GCR's, WWER 440 (types 230 and 213), WWER 1000 and RBMK's (Table 3).

More than 500 experts around the world have now been trained in the ASSET assessment techniques.

The ASSET service was set up to review operational safety experience particularly focussing on events, to investigate, and identify the direct causes of incidents or accidents and their root causes, the generic safety lessons learned and the appropriateness of corrective actions taken. A typical mission generally comprises 6 experts and takes 2 weeks to conduct.

Although sound design is widely recognized to be a prerequisite for safe operation, it is not sufficient. An active operating management is also a key factor to ensure safe operation.

The various options offered by the ASSET Services to the IAEA Member States have now been expanded to include 5 types:

**Type S** Seminar Training of operators and regulators on use of the ASSET methodology to identify the safety issues, to assess their consequences to safety and to eliminate the root causes of the future accidents and incidents.

**Type R** Review of the plant operational safety performance, to assess appropriateness of corrective actions and to exchange views on further enhancement of the plant Safety Culture for effective management of prevention of incidents.

**Type A** Review of the root cause Analysis of an event very significant to safety in order to disseminate generic recommendations on effective prevention of incidents with similar root causes at other power plants.

**Type I** Assistance to plant management in Implementing the ASSET recommendations regarding the incident prevention programme (quality control, preventive maintenance, surveillance) and the experience feedback programme (root cause analysis, repairs and remedies).

**Type P** Follow-up of the plant Safety Culture regarding management of prevention of incidents as a result of the implementation of the recommendations of an ASSET mission Type R.

The ASSET Methodology. The ASSET investigation methodology now provides the practical guidance to eliminate in advance the root causes of the future incidents and accidents.
It provides assessment of the operational safety performance resulting from the managerial practices which identifies the safety issues, assess their significance and identifies their root causes.

**Results.** Many recommendations resulting from the in depth assessment of plant operational safety performance and from the detailed root cause analysis of the plant safety issues have been made to Operating and Regulatory Organizations:

The specific corrective actions offered to NPPs have addressed the following major findings:

- The Root Causes of the Three Mile Island and the Chernobyl accidents are still not yet completely eliminated at many nuclear power plants.
- The three operating elements pertinent of any accident, proficiency of personnel, operability of equipment and adequacy of procedures are not permanently meeting acceptance criteria.
- Identification and elimination of the root causes of deviations is not systematically carried out to prevent the occurrence of any incidents and accidents.

The ASSET methodology was adopted by all plants visited and made part of the regulatory requirements by the countries having hosted ASSET missions.

### 3.0 EASTERN EUROPEAN ACTIVITIES

Reactors of all types designed in the former USSR make up about 15% of the world's operating reactors and about 42% of those under construction. Of the Soviet pressurized light water reactors (water cooled, water moderated energy reactors (WWERs)), which are the only type to have been exported, there are a total of 44 in operation and 25 under construction. In eastern Europe there are, in addition to Soviet designed WWER plants, five Canadian designed heavy water reactors under construction in Romania and a Westinghouse pressurized water reactor in operation at Krsko in Slovenia.

The dependence of eastern European countries on nuclear electricity is considerable. In 1990 the nuclear share of electricity production was 51.4% in Hungary, 35.7% in Bulgaria, 28.4% in Czechoslovakia, and 12.2% in the USSR.

#### 3.1 WWER Plants

**Background.** As of March 1992 there are 10 first generation 440 WWER Model 230 (WWER-440/230) plants in operation. Two units
in Armenia and four in the eastern part of Germany have been shut down (Table 4). Four of the operating units are in Bulgaria, two are in Czechoslovakia and four are in the Russian Federation. All of these units lack safety features basic to other PWRs. The weaknesses include limited emergency core cooling capability, insufficient redundancy and separation of safety equipment, deficient instrumentation and control systems, insufficient fire protection and the lack of a containment to enclose the reactor systems.

A further concern is that the safety relevant systems outside the reactor cooling system use standard equipment with no nuclear grade quality requirements.

These units clearly do not meet current safety requirements. Nevertheless, there are some positive features, such as the relatively low core power density and the large water inventory in the primary and secondary circuits, which make these reactors less sensitive to disturbances than more modern light water reactors.

In the second generation of 440 MW WWERs, the Model 213, many of the design deficiencies of the Model 230 have been eliminated. The design basis accidents have been redefined and include break sizes up to a complete rupture of the main coolant pipes (500 mm in diameter). Physical separation and redundancy of safety systems (3 x 100%) correspond to international practice. In addition, the Model 213 design includes sealed chambers to localize accidents and a steam suppression system. Of the 16 units in operation (Table 5), the two reactors in Finland have undergone significant safety improvements, particularly in manufacturing quality and the use of non-Soviet instrumentation and a containment structure surrounding the reactor systems. At this time there are four Model 213 units under construction in Cuba. As with the units in Finland, the Cuban plant incorporates a containment structure as well as a number of additional safety improvements.

The safety concept of the larger and more modern third generation of Soviet designed 1000 MW WWER plants is similar to that of non-Soviet PWR plants in operation worldwide and includes a full containment structure. However, some concerns related to design and operational problems remain, even for the more advanced 1000 MW units, mainly about core safety and instrumentation and control. Of the 18 units in operation, only the two in Bulgaria are outside the Russian Federation. Nineteen other units are under construction in the former USSR and two units are under construction in Czechoslovakia (Table 6).

IAEA WWER Programme. In response to requests from Member States operating Soviet designed WWER-440/230 plants for assistance from the IAEA's nuclear safety services, a major
international Programme was begun to evaluate these first generation reactors as a complement to relevant national, bilateral and multilateral activities. The IAEA Programme is extrabudgetary and depends on voluntary contributions from Member States.

The objective is to assist countries operating WWER-440/230 plants to perform comprehensive safety reviews aimed at identifying design and operational weaknesses. The review should form the technical basis for the decision on enhancing safety which must ultimately be taken by the countries operating those plants.

An Advisory Group met in September 1990 to establish the technical scope and a work programme. The meeting was attended by 42 participants from 19 Member States and from the Commission of the European Communities (CEC) and the World Association of Nuclear Operators (WANO).

The Advisory Group agreed upon a programme including:

(a) A review of the design concept in order to obtain an overview of the safety aspects of WWER-440/230 plants;

(b) Safety review by teams of international experts to the individual reactor sites in order to evaluate plant specific design deficiencies and the conduct of operations, maximum use being made of the IAEA's experience in the provision of safety services - particularly through Operational Safety Review Teams (OSART) and Assessment of Safety Significant Events Teams (ASSET) missions; and

(c) Studies on matters of generic safety concern such as reactor pressure vessel embrittlement, the applicability of the leak before break concept, accident analysis re-evaluations using modern computer codes and the conduct of probabilistic safety assessments (PSAs).

A Steering Committee was established to monitor the Programme and to provide technical guidance to the IAEA on the resolution of safety issues and the prioritization of activities.

Programme co-ordination lies with the IAEA Secretariat. The schedule of activities through December 1991 is shown in Fig. 3.

Design Concept Review. In February 1991, the IAEA with the participation of 32 safety experts from 10 countries and 25 USSR specialists, conducted a review of the design concept of WWER-440/230 plants.

In general the basic design was found to be conservative showing evidence of the high priority given to plant availability. However, compared to the current practice in the
case of other PWRs, the design basis and safety features are very limited.

Safety analysis had been performed only for a limited spectrum of potential accidents. There has been no comprehensive accident analysis.

In addition, the design concept review pointed to differences between various WWER-440/230 plants, confirming the importance of plant specific safety reviews. It has also provided a valuable checklist of problems to be investigated during the safety review missions.

**Safety Review Missions.** Safety review missions have been conducted at all four individual sites with WWER-440/230 plants in operation, namely:

- Bohunice, Units 1-2 (Czechoslovakia), 8-26 April 1991
- Kozloduy, Units 1-4 (Bulgaria), 3-21 June 1991
- Novovoronezh, Units 3-4 (USSR), 12-30 August 1991
- Kola, Units 1-2 (USSR), 9-27 September 1991

In this set of on-site reviews, international teams of about 15 experts each have assessed not only the plant specific design deficiencies but also the overall conduct of operations. The scope of the reviews included:

- core design
- system analysis
- mechanical and component integrity
- instrumentation and control
- electric power
- accident analysis
- fire protection
- plant management and organization
- quality assurance
- operator training and qualification
- conduct of operations
- maintenance
- technical support
- emergency planning.

Basic design deficiencies were confirmed; the value of a number of design strengths and specific plant modifications also became evident. Moreover, major operational shortcomings were identified.

In addition, the IAEA has carried out missions to the Bohunice and Kozloduy sites to review the safety of these plants with respect to seismic hazards, with emphasis on - inter alia - the design acceleration under earthquake conditions and the seismic vulnerability of structures and components important for safety.
The original design of WWER-440/230 plants did not take into account external hazards, in particular earthquakes. For this reason, at least the two sites investigated have major seismic weaknesses with respect to seismic hazards.

**Results.** An important part of the IAEA Programme was the evaluation of the safety significance of the deficiencies during the design concept review and safety review missions.

Specific recommendations concerning the deficiencies identified, suggestions or questions open for further investigation are called safety items. Individual safety items related to the same major safety concern have been grouped in categories identifying broader safety issues.

Issues related to both design and operation were ranked according to their safety significance in four categories of increasing severity.

- **Category I:** Issues in Category I shown a departure from recognized international practices. It may be appropriate to address them as part of actions to resolve higher priority issues.

- **Category II:** Issues in Category II are of safety concern. Defence in depth is degraded. Action is required to resolve the issue.

- **Category III:** Issues in Category III are of a high safety concern. Defence in depth is insufficient. Immediate corrective action is necessary. Interim measures might also be necessary.

- **Category IV:** Issues in Category IV are of the highest safety concern. The defence in depth is unacceptable. Immediate action is required to overcome the issue. Compensatory measures have to be established.

In order to assist the Governments to set priorities for the corrective measures required at their plants, two Programme review meetings were convened by the IAEA in 1991. About 1300 specific safety items identified during the safety reviews and in the design concept review have been grouped in broader categories representing some 100 safety issues.

Tables 7 and 8 provide consolidated statistics on the safety issues grouped by area and according to their safety significance (category).
Future Programme Activities. The second phase of the IAEA Programme will focus on helping countries to make the best use of the assistance that they receive through - for example - the CEC and WANO. Such assistance should be in line with the recommendations resulting from the first phase of the IAEA Programme and should not duplicate work already completed or initiated internationally or within the framework of national regulatory bodies and the strengthening of the technical capabilities.

It has also been suggested that the IAEA participate in the co-ordination between the OECD group of 24 countries as a special technical adviser for identifying priorities and providing technical recommendations.

At present, to varying degrees, programmes for safety improvements are being pursued at all plants.

The 1992 IAEA Programme activities are focused on three major areas where assistance is required, namely: assistance for the resolution of country or plant specific problems; study of generic safety issues; and co-ordination with other bilateral and international programmes, plus continuing assistance in the development of a safety analysis report for the WWER Model 213 NPP, and the setting up of an appropriate programme on the safety of the WWER-1000 NPP.

3.2 RBMK Plants

In the former USSR there are also 16 large RBMK (light water cooled, graphite moderated) reactors of the Chernobyl type in operation and four under construction (Table 9). In 1990, RBMK plants generated 47.8% of the total nuclear electricity in the USSR. As of the beginning of 1991, RBMK reactors accounted for 45% of the total nuclear generating capacity. Since the Chernobyl accident the safety of these reactors has been a matter of great international concern.

RBMK reactors were designed in the 60's and do not conform with current safety requirements. Various analyses of the Chernobyl 4 accident have revealed safety deficiencies in design and operation. As a result a programme of major backfittings and operational changes has been implemented. During the IAEA nuclear safety conference in 1991 the participant from the former USSR suggested an international project to review the safety of these reactors, which was followed by a formal request to the IAEA.

A meeting with participation from the Russian Federation, the Ukraine, Lithuania and six European countries, along with the CEC and IAEA as observers was held in October 1991 in Moscow to discuss an international project on "Safety of Design Solutions
and Operation of NPPs with RBMK Reactors. The project would encompass in its first phase nine areas (System Engineering, Protection Systems, Core Physics, External Events, Engineering Quality, Operating Experience, Human Factors, Regulatory Aspects, PSA). Several significant bilateral programmes have also been initiated.

Co-operation on RBMK reactors was discussed at the G-24 meeting in December 1991. At this meeting and at the Moscow meeting the IAEA suggested that a programme be initiated similar to that in progress for the WWER 440/230 reactors.

Lithuania, Russian Federation and Ukraine have requested the IAEA to conduct ASSET missions to RBMK plants.

In view of the situation the IAEA convened a Technical Committee Meeting in April this year to provide a technical basis for a co-ordinated action programme to improve RBMK safety and to facilitate the co-ordination of national, bilateral and international activities. The objective of the meeting was set: "to compile, review and exchange experience from various national and bilateral programmes aimed at assessing the safety of RBMK reactors". The meeting included in-depth technical presentations on results obtained so far, discussion of areas needing further analysis and identification of programmes for future co-operation. Specific conclusions were as follows:

i) The need to perform a comprehensive safety review of RBMK reactors, taking into account plant specific features, was considered a most important task to be undertaken. Main weak points should be identified with regard to generally accepted safety principles. This review should make use of all existing analysis and reports with recommendations on RBMK safety improvements.

The generic technical areas requiring improvements have been clearly identified in the various proposals (e.g. Consortium, Memorandum with common positions between Russian Federation, Lithuanian Republic and Ukrainian Republic).

ii) Effective co-ordination between IAEA funded, CEC funded, WANO and bilateral activities is needed. The establishment of a Liaison Secretariat with well defined responsibilities should be explored between IAEA, CEC and the World Bank. This will avoid undue duplication of efforts and optimize actions.

3.3 Other IAEA Activities

The IAEA review activities to date have identified the need for assistance to regulatory authorities in eastern Europe. This need has intensified with the emergence of the independent states
in the former USSR. The IAEA is co-operating with the CEC in this regard in particular to review the capabilities of the new regulatory bodies and providing the assistance to enable them to properly fulfill their role in the pursuit of nuclear safety.

4.0 RESULTS OF THE 1991 INTERNATIONAL SAFETY CONFERENCE

The "International Conference on the Safety of Nuclear Power: Strategy for the Future" held in Vienna, September 1991 made a number of recommendations for the enhancement of nuclear safety.

Of particular note is the recommendation that:

"There is a need to consider an integrated international approach to all aspects of nuclear safety, including safety objectives for radioactive wastes, which would be adopted by all Governments, and in this connection, the potential value of a step-by-step approach to a framework convention is recognized: and, therefore the Conference requests the Governing Bodies of the IAEA that they organize the preparation of a proposal on the necessary elements of such a formalized international approach, examining the merits of various options and taking into account the activities and roles of relevant international and intergovernmental bodies and using the guidance and mechanisms already established in the IAEA".

Work on a possible international safety convention is presently underway with 2 international expert group meetings having been held.

In addition with respect to operating nuclear power plants the Conference also recommended that:

i) The IAEA should initiate a process to develop a common basis on which the acceptable level of safety of all operating nuclear power plants built to earlier standards can be judged. In some cases, international co-operation and support will be necessary to ensure the completeness of safety reviews and the adequacy of implementation of measures to achieve that acceptable level of safety.

ii) The Governing Bodies of the IAEA are invited to develop a more vigorous overview process with the objective of achieving a high safety performance in all operating plants, inter alia by expanding and strengthening services such as ASSET and OSART services, and by promoting the achievement of sufficient national regulatory oversight.

Activities in response to these recommended are in the process of development for the future IAEA Programme.
<table>
<thead>
<tr>
<th>Country</th>
<th>Total No. of Operating Units</th>
<th>Missions</th>
<th>Reactor Type</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brazil</td>
<td>1</td>
<td>2</td>
<td>PWR</td>
<td>1985, 1989</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>6</td>
<td>4</td>
<td>PWR</td>
<td>1990, 1991</td>
</tr>
<tr>
<td>Canada</td>
<td>20</td>
<td>1</td>
<td>PTR</td>
<td>1987</td>
</tr>
<tr>
<td>China</td>
<td>-</td>
<td>2</td>
<td>PWR</td>
<td>1989, 1990</td>
</tr>
<tr>
<td>Finland</td>
<td>4</td>
<td>2</td>
<td>BWR, PWR</td>
<td>1986, 1990</td>
</tr>
<tr>
<td>France</td>
<td>56</td>
<td>4</td>
<td>PWR</td>
<td>1985, 1988, 1992</td>
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<td>Hungary</td>
<td>4</td>
<td>1</td>
<td>PWR</td>
<td>1988</td>
</tr>
<tr>
<td>Italy</td>
<td>-</td>
<td>2</td>
<td>BWR</td>
<td>1987, 1988</td>
</tr>
<tr>
<td>Japan</td>
<td>41</td>
<td>2</td>
<td>BWR, PWR</td>
<td>1988, 1992</td>
</tr>
<tr>
<td>Mexico</td>
<td>1</td>
<td>3</td>
<td>BWR</td>
<td>1986, 1987</td>
</tr>
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<td>2</td>
<td>BWR, PWR</td>
<td>1986, 1987</td>
</tr>
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<td>2</td>
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<td>1985, 1989</td>
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<td>-</td>
<td>2</td>
<td>PWR</td>
<td>1984, 1985</td>
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<td>-</td>
<td>1</td>
<td>PWR</td>
<td>1989</td>
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<td>-</td>
<td>1</td>
<td>PTR</td>
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<td>PWR</td>
<td>1991</td>
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<td>1987, 1990</td>
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<td>GCR</td>
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<td>1</td>
<td>PWR</td>
<td>1984</td>
</tr>
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</table>

**BWR = Boiling Water Reactor, PWR = Pressurized Water Reactor, PTR = Pressure Tube Reactor, GCR = Gas Cooled Reactor**
Table 2
Member States Participating in the OSART Programme
1983 to December 1991 - Experts and (Observers)

<table>
<thead>
<tr>
<th>Country</th>
<th>Experts</th>
<th>Observers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argentina</td>
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<td></td>
</tr>
<tr>
<td>Austria</td>
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<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Brazil</td>
<td>4 + (9)</td>
<td></td>
</tr>
<tr>
<td>Bulgaria</td>
<td>1 + (11)</td>
<td></td>
</tr>
<tr>
<td>Canada</td>
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<td></td>
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<tr>
<td>China</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td>CSFR</td>
<td>6 + (5)</td>
<td></td>
</tr>
<tr>
<td>Cuba</td>
<td>(7)</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>France</td>
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<td></td>
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<td>Germany</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Hungary</td>
<td>5 + (5)</td>
<td></td>
</tr>
<tr>
<td>India</td>
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<td></td>
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<tr>
<td>Italy</td>
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<td>Japan</td>
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<tr>
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<tr>
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<td>U.K.</td>
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<td>U.S.A.</td>
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<tr>
<td>U.S.S.R.</td>
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<td>8 + (2)</td>
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<td>10 + (4)</td>
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TOTAL OF 377 EXTERNAL EXPERTS PLUS 94 OBSERVERS
Table 3
ASSET Missions - Conducted & Planned
from 1986

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<th>Country</th>
<th>Type</th>
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<th>Reactor Type</th>
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<td>PWR</td>
<td>1991</td>
</tr>
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<td>PWR</td>
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<td>S</td>
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<td>PWR</td>
<td>1992</td>
</tr>
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<td>PWR</td>
<td>1990,92,93</td>
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<td>S</td>
<td>1</td>
<td>PWR/BWR</td>
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<td>PWR</td>
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Table 4
WWER-440 Model 230 Reactors in Operation
(or Shut Down)

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<td>1972</td>
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<td>1973</td>
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<td></td>
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<td></td>
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<tr>
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* WWER-440 Model 318
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Table 9
RBMK Reactors in Operation and Under Construction

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<tr>
<td>Kursk</td>
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<td>2</td>
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<td>-</td>
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FIG.1 Numbers of nuclear power reactors in operation (as of December 1991) by world region (including 6 reactors in Taiwan, China.) (Source: IAEA Power Reactor Information System (PRIS). Non-governmental information.)
FIG. 2 Numbers of nuclear power reactors under construction (as of December 1991) by world region. (Source: IAEA Power Reactor Information System (PRIS). (Non-governmental information.)
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<tr>
<td>15-16</td>
<td>Kola</td>
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<td>Bohunice</td>
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**Legend:**
- Pre-vist: Pre-meeting
- Mission or meeting: Meeting
- ASSET review: ASSET review
- Workshop: Workshop
- Seismic review: Seismic review
- Generic studies: Generic studies
SESSION 9

SAFETY IN DESIGN, OPERATIONS, REGULATION

SESSION CHAIRMAN

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ABSTRACT

SAFETY PRINCIPLES IN DESIGN

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After 25 years of safe electricity production the CANDU system can be considered a mature design concept. The "defense in depth" foundation of the Canadian safety philosophy, like that of many other countries, relies on designing the plant such that the radioactive materials are contained within a succession of physical barriers. This basic concept recognizes that in spite of the best effort of designers and operators, equipment failures and operator errors may occur such that one or more of the physical barriers to radioactivity release is breached. This approach leads to a multi barrier, multi level "defense in depth" system which is tolerant to a wide range of equipment failures and human errors.

While following the widely accepted international standards documented in the IAEA Safety Guide "General Design Safety Principles for Nuclear Power Plants", lessons learned from the NRX accident has lead to specific criteria for nuclear power plants in Canada. These include a requirement that the process and special safety systems must be physically and functionally separate, diverse and independent to the maximum extent practicable, and these systems must be testable with testing programs implemented to demonstrate continued capability to meet performance specifications.

From a control room operators point of view there are three basic functions which must be undertaken following an accident in order to limit the consequence to the public from any accident (1) shutdown, (2) cooldown, and (3) contain. This paper discusses the various safety design principles incorporated into the special safety and safety support systems which are provided to the operator to enable him to undertake these functions.

Recent experience has shown that the multitude of tasks facing an operator, each of which on its own may be straightforward, has lead to a complexity of operation which has a potential impact on safety. Thus future CANDU designs are focusing on an overall reduction in complexity, both in the design of simpler systems for normal operation and in the way the design mitigates potential accidents, and by providing more user friendly tools to allow the operator to do his job.
SAFETY PRINCIPLES IN DESIGN

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1. INTRODUCTION

After 25 years of safe electricity production the CANDU system can be considered a mature design concept. Over the last 20 years the CANDU system has consistently placed in the top ten power reactors over 500MW and lifetime capacity factors have been about 5% greater than other reactor types. The environmental impact of these stations has been highly beneficial in displacing potential SO\textsubscript{x} and NO\textsubscript{x} releases from coal fired plants. Offsite radiation releases from normal operation have been typically less than one percent of the allowable limit. The CANDU safety record has been exemplary with no major accidents and no member of the public receiving a radiation dose even close to the regulatory limit. This excellent safety record did not just happen by chance. It came about by application of safety principles during both the design and operating phases of the plant life. This paper will concentrate on those safety principles associated with the design of CANDU plants, and then describe how future CANDU designs will continue to evolve from these fundamental safety design principles.

The foundation of our safety philosophy, sometimes termed "defense-in-depth", is established by designing, constructing and operating a nuclear power plant in such a manner that the radioactive materials are contained within a succession of physical barriers (1,2,3,4,5). This basic concept, similar to that adopted in other countries, recognizes that in spite of the best efforts of designers and operators, equipment failures and operator errors may occur such that one or more barriers to radioactivity release is breached. The safety approach, therefore, requires that more than one "level" of safety be provided for each barrier for a range of postulated accidents that may threaten the barrier. This leads to a multi-barrier, multi-level "defense-in-depth" system which is uniquely tolerant to a wide range of equipment failures and human error. This overall safety design approach, including the special safety features, has led to an excellent safety record in operating nuclear generating stations and provides the confidence that risk from these stations can be maintained at a low level.

The safety approach presented here is intended to provide a concise account of the basic principles which govern the design requirements of a nuclear power plant. The safety approach (6) and its application to requirements of design for safe operation, safety analysis and accident management constitute a code of
practice that is internationally accepted. The major safety principles thus derived are as follows (6):

a. The principal goal of nuclear safety shall be to keep radiation exposure of the public and the site personnel within appropriate prescribed limits in all operational states and within acceptable limits in accident conditions;

b. Nuclear power plants shall be designed, constructed and operated to an appropriate quality level to minimize the likelihood of a failure which could lead to the escape of significant quantities of radioactive material;

c. Escape of radioactive material shall be restricted by successive physical barriers, some of which are present because they have functions to perform in power operations, others serving safety purposes only;

d. Consideration shall be given to all postulated initiating events that may render any of these barriers ineffective;

e. All design provisions and necessary operator actions which are required to:

1. maintain intact those barriers which prevent the escape of radioactive material,
   or
2. mitigate the consequences of barrier failure.

shall be identified for each postulated initiating event and shall be part of the design basis for the plant.

The purpose of the safety approach, as highlighted here, is to maintain the plant in a normal operating state. In addition, the objective is to ensure the correct short term response following an unanticipated event and to facilitate the long term management of the plant following accident conditions.

The Canadian defense-in-depth approach to nuclear safety is strongly influenced by the early Canadian experience with the NRX reactor accident in 1952. The cause of the accident was attributed to operator error compounded by faulty indication of equipment status, but in retrospect, insufficient attention had been given by the designers to potential failure modes of the safety systems.

The most important lessons learned from the NRX accident were related to shutdown system design. There was no automatic shutdown system action to terminate the overpower, the operator had to be relied upon. Failure of the air system resulted in a common mode failure which prevented all of the rods from dropping. As a result, principles of redundancy, independence
ard diversity were introduced to improve the reliability of future automated shutdown systems.

The criteria for nuclear power plants in Canada which flow from this general approach include the following (7):

1. the design and manufacture of components and the design and construction of systems and structures must be in accordance with nationally or internationally accepted engineering codes and standards;

2. process and special safety systems must be physically and functionally separate, diverse and independent to the maximum extent practicable;

3. process and special safety systems must be testable and testing programs must be implemented such as to demonstrate continued capability to meet performance specifications;

4. redundancy is required in all safety-related control, monitoring and initiation systems; and

5. the selection and training of operations personnel must be such as to ensure continued compliance with the high standards which have characterized nuclear operations in Canada.

The multiple barrier principle (2,3) is an important element in the philosophy of safe nuclear plant design. In its simplest form, the barriers are as follows:

a. the uranium dioxide (UO₂) fuel, which contains almost all the radioactivity, is a ceramic with high melting point sealed in a corrosion resistant metallic cladding;

b. the zirconium alloy fuel element sheath;

c. the reactor cooling system;

d. the containment system capable of containing most of the radionuclides if the above fail;

e. exclusion boundary which provides a separation between the station and the public.

2. SAFETY LEVELS

One representation of the levels of safety provided in the CANDU nuclear operating station is illustrated in a matrix form in Figure 1. The first two levels of safety, in general, are capable of dealing with a large majority of safety concerns. However, the third level receives the most attention since the
postulated failures at this level are not only more serious, although low frequency events, but they are also used to set the design bases for the special safety systems. Designing the special safety systems to deal with these major, extreme accidents leads to large margins of safety for more likely events.

In dealing with all plant upsets or accidents, the control room operator must undertake four important functions:

- shut down the reactor
- cooldown the system
- contain any released fission products, and
- monitor the system to ensure a continued safe shutdown state.

In going from level one to three events his actions should be one of continued evolution in the sense that he should not be required to do something that is foreign to his normal way of operating the reactor. The decision to activate the special safety systems is, however, not a normal procedure and the decision to activate them should to the maximum extent possible be fully automated. The operator's role then becomes one of situation management to ensure that these systems are fulfilling the four basic safety functions.

It is normal operating practice for example to have two available heat sinks under all operating conditions, e.g. heat transport system and shutdown cooling system; steam generator feedwater system and auxiliary feedwater system.

2.1 First Level of Safety

The aim of the first level of defence is to prevent deviation from normal operating conditions. This requires that the plant be soundly and conservatively designed, constructed and operated in accordance with appropriate quality levels and engineering practices.

2.1.1 Equipment Quality. The first and foremost level of safety provided in nuclear generating stations is the design, construction and operation of the nuclear process systems to a high quality level. Process systems, such as the heat transport system, are designed to codes and standards which demand the highest quality in design, material and workmanship. These standards were developed for the nuclear industry and they reflect a much higher level of quality than is applied to conventional process systems. In addition, these systems undergo an extensive in-service inspection and maintenance program to provide continued assurance of a high level of integrity. The Quality Engineering (QE) and Quality Assurance (QA) program documentation provide the evidence that the design, supply,
construction and operating practices conform to the required standards.

2.1.2 **Process and Control Systems.** The plant process and control systems are designed to be able to cope with a range of anticipated failures in plant equipment. This is achieved through automatic control action or starting standby equipment, or by regulating systems that can automatically adjust control values to accommodate changed system conditions. Such actions prevent the failures from degenerating into serious accidents. Active systems such as the reactor regulating system are designed with redundant components so that many single equipment failures, and in some cases multiple equipment failures, will not cause a loss of the process function. In addition, a great amount of effort is put into system design so that, where possible, failures which lead to a loss of the process function result in a safe action. The dual computer control system is an example of this approach. Each computer processes the input information and provides an output of a control action based on these inputs. If the computer fails to execute the necessary steps, this failure is detected and control is transferred to the other computer. If this computer similarly fails, all control output signals are set to a safe value, resulting in a reactor shutdown.

The regulating system is also provided with safety features via the setback and stepback routines. When conditions arise outside the normal scope of the control function, a setback will lower reactor power by rapid draining of the liquid control zones or by insertion of the control absorbers. Should the upset conditions require a more rapid power reduction, the control absorbers drop rapidly under gravity with spring assistance to get them going. For level one upsets, it is not always necessary to completely shut down the reactor to remove the cause of the out-of-bound parameter so setbacks and stepbacks have varying endpoints depending on the nature of the original upset. This allows maximum power production while ensuring an adequate level of public safety and investment protection for the operators. Safety systems remain poised throughout such events to cope with possible deterioration of the initiating condition.

2.2 **Second Level of Safety**

The aim of the second level of defence is to detect, in a timely manner, and intercept deviations from normal operating conditions in order to prevent an operational occurrence from escalating into an accident condition. This recognizes the fact that during the service life of a nuclear power plant, events will occur which will challenge the integrity of the system. This level, therefore, requires the provision of specific systems and definition of operating procedures to prevent or minimize damage from anticipated initiating events.
To cater to process upsets or equipment failure that are beyond the capability of the process systems described above, all CANDU reactors have installed a number of additional systems, called "Special Safety Systems" that do not contribute at all toward the plant's main purpose of generating electricity. To the greatest extent possible, these systems are independent of the normal process systems and from each other, especially in the realm of initiating signals. It is impractical to supply completely independent supplies of electrical power, instrument air, service water, etc, but attempts are made to minimize any interaction and to generally make the systems fail safe in the event of loss of instrumentation power or instrument air. For each reactor there are three types of special safety system:

a. Shutdown System
b. Emergency Coolant Injection System
c. Containment System.

In addition to these major system types, the latest designs also include a number of back-up process systems that improve the reliability of supply of electrical power and heat removal systems.

2.2.1 Shutdown Systems. Incorporated in the design of all CANDU nuclear plants since Pickering NGS A, are two independent, diverse shutdown systems. Figure 2 shows a simplified representation of the two systems. Both systems have sensing circuits which monitor the status of a range of parameters and trip logic which initiates the shutdown action.

On SDS1 the reactor trip is effected by a set of neutron absorbing shutoff rods. These rods are normally held above the reactor by electro-magnetic clutches. On receipt of a trip signal (or loss of power) the clutches are de-energized and the SOR's drop quickly into the calandria by gravity. In later designs the rods receive additional initial acceleration from a compressed spring.

For SDS2 a liquid poison (gadolinium nitrate dissolved in D₂O) is injected into the moderator through a set of eight horizontally oriented injector nozzles. The liquid poison absorbs the neutrons required to maintain the fission process, thereby shutting down the reactor. The liquid poison is held in a set of tanks connected to a high pressure helium gas supply through a set of fast acting valves. On receipt of a trip signal or on loss of electrical power or instrument air, these valves are opened rapidly, pressurizing the liquid poison tank and forcing the poison into the moderator.

Important points to note are the diversity in the two methods of shutting down the reactor, the physical separation between the two systems, and their fail safe nature. The cabling, tubing and equipment associated with the sensing and trip logic systems are
also physically separated. To the maximum practical extent, different equipment from different suppliers is used in the two systems where the same function is performed.

A number of plant variables are measured by each of the shutdown systems to determine when the system should be actuated. Sufficient variables are independently measured by each system that proper system operation can be reliably assured at all power levels and for all configurations allowed for normal operation. Where practicable two trip signals on different variables are provided on each shutdown system for each postulated event.

The process variables are combined in a two out of three majority vote logic which allows very reliable system operation while at the same time rejecting spurious operation of a single measurement. The majority vote scheme also allows testing of the instrumentation and logic during service which contributes to its very high, demonstrated reliability. If a failure is detected during testing, the particular logic channel can be placed into a safe state so that operation of either of the remaining logic channels will cause system actuation.

2.2.2 **Emergency Coolant Injection System.** The emergency coolant injection system (ECIS) is designed to inject a reserved supply of light water into the heat transport system in the event that the loss of normal coolant cannot be made up by the normal process systems (a "loss-of-coolant" accident or LOCA). A simplified schematic of the Bruce NGS B ECIS is shown in Figure 3. The system is made up of a high pressure supply of light water in the form of a set of accumulator water tanks and gas tanks and a lower pressure long term injection system involving a containment recovery sump, recovery pumps, storage tank and heat exchangers.

On detection of a LOCA, emergency coolant injection is initiated. The accumulator gas valves open along with the valves in the ECI supply lines to the accident unit. The HP gas drives the water from the accumulator water tanks into the headers of the accident unit. Once the accumulator storage tanks are depleted, water is pumped from the grade level storage tanks into the accident unit. At Pickering NGS and Darlington NGS the initial injection uses electrically driven high pressure pumps which draw water from a storage tank. In parallel with this initial injection the ECI recovery pumps are started. In the long term, the coolant discharged from the break collects in a central containment recovery sump where it is recirculated through heat exchangers back into the accident unit. Although the emergency coolant injection systems at each station differ somewhat, they are all effective at meeting their design objectives.

In a fashion similar to the shutdown systems, the ECI system also employs an independent multi-channel majority vote logic system
that allows complete testing of the initiating and control logic while the system remains operational.

Besides redundancy in the instrumentation systems, the ECI system also has redundancy in its mechanical equipment. This redundancy allows full functional testing of the mechanical equipment such as isolating valves, pumps and heat exchangers.

2.2.3 Containment Systems. The final barrier to the release of radioactivity to the environment in the event of an accident is the containment system. This system ensures that only a minimal amount of radioactivity will escape in the remote possibility that some combination of events should result in a release of activity within its boundary.

The containment system provided for all Ontario Hydro's current and planned nuclear generating stations is of the vacuum containment concept. In addition to the concept of vacuum containment, the system incorporates further notable design features which result in a system that is almost entirely self-actuating. That is, the major features of the system will respond as required without any external power requirements, or any need to signal or actuate active devices.

The containment system comprises the reactor building concrete envelope, a large concrete duct connecting the reactor building to a valve manifold containing several large valves in parallel, the valves themselves which separate the duct from the vacuum building, and the vacuum building. The large volume of the vacuum building is kept evacuated at an absolute pressure of about 10 kPa (1.5 psi absolute). The vacuum building also contains a self-actuating dousing system, which works on the syphon principle, which will cool and condense water and steam which enter the vacuum building.

Operation of the negative pressure containment system following a large LOCA is shown diagrammatically in Figure 4. There is a large release of steam into the Reactor building which results in a rapid increase in containment pressure. The self-actuated Pressure Relief Valves open automatically at 7 kPa (1 psig). The steam enters the Vacuum Building where the pressure increase actuates the dousing system. The resultant spray condenses the steam, thereby reducing the pressure. For the largest break size the pressure peaks within the Reactor Building accident vault in 3s and returns to subatmospheric in about 60s.

Assuming no containment impairments, the pressure slowly returns to atmospheric pressure as a result of the small inleakage of air from outside through the structures and because of the consumption of instrument air by equipment located within the containment.
When containment pressure returns to atmospheric, the Emergency Filtered Air Discharge System (EFADS) is brought into operation to control the pressure slightly sub-atmospheric. EFADS is equipped with particulate filters and charcoal filters for iodine removal, and radiation monitoring equipment to measure any radioactive releases from the station.

Hydrogen which can be produced by a Zircalloy/steam reaction during a LOCA is removed from the containment atmosphere by controlled ignition. The system utilizes a set of igniters located inside the Reactor Building vaults. The igniters are activated automatically on a containment "buttonup" signal. Ignition will occur when the post accident hydrogen concentration increases to the flammability limit and the humidity which suppresses ignition decreases.

In New Brunswick and Quebec and overseas, AECL designed single CANDU units also include similar dousing water suppression systems and filtered air discharge as shown in Figure 5.

2.3 Third Level of Safety

For the third level of safety it is assumed that, although very unlikely, the escalation of certain events may not be arrested by a preceding level and so additional safety systems, equipment and procedures are provided to control the consequences of the resulting accident conditions.

Thus for reactor shutdown, as described in Section 2.2.1, CANDU includes a second independent, diverse shutdown system.

Another design feature of CANDU reactor cores is that the interstitial space between fuel channel assemblies is occupied by a completely separate, relatively cool, low pressure D\textsubscript{2}O moderator. This fluid has two normal purposes; slowing down fast neutrons from the fission process to thermal velocities where they are again likely to cause fission of uranium atoms, and removing heat from reactivity devices, guide tubes, and calandria structures.

However, for certain loss-of-coolant accidents the moderator also maintains the fuel channel assemblies in a coolable geometry until the emergency coolant injection system is effective. In addition, if the ECI system should fail for some reason, the fuel channels will overheat and the pressure tube will sag into contact with the calandria tube, with fuel bundles slumped onto the bottom of the pressure tube. Heat transfer by conduction is sufficient to remove the decay heat so that fuel channel integrity is maintained. Thus the presence of the moderator virtually eliminates any concerns with the core melt accident.

2.4 The Operator. The operator and operations staff are crucial to plant safety. The role of the designer is to provide the
tools to the operator and operation staff so that the most effective balance of reliable safe operation and response to accidents can be achieved.

Systematic consideration of human factors and the human-machine interface is an integral part of the design process which begins at the conceptual design stage and continues throughout the operational phase. The objective is to provide the operator clear displays of parameters that indicate the status of all equipment and systems necessary to achieve safe operation, or shutdown, if required, and to provide the controls to allow the required operator response. The design principles for information display and controls aim to promote the success of operator actions in the light of the time available, the expected physical environment and the psychological pressures. The need for operator intervention on a short-time scale is kept to a minimum, and the design generally takes into account the fact that such intervention is only acceptable if it can be shown that the operator has sufficient time to decide and to act.

2.4.1 Operator Controls. Besides the automatic controls described earlier, there are manual controls, displays, alarms, and set point adjustments with which the operator interacts with the plant. The majority of these controls for each four unit stations are located in a main control room, centrally positioned in the generating station. The controls are grouped in a logical fashion, by major plant system, on control panels which make up the walls of the control room.

The design of the control panels is carried out by a team of specialists in the field of human factors engineering and human-machine interface techniques. They employ such error reducing techniques as grouping equipment controls and indicators on mimic panels, standardized position indicators for valves, breakers, dampers etc., and announcing important alarms with alarm windows. On more modern plants, extensive use of custom-designed CRT information display systems is employed to present to the operator the large amount of information entering the control room in a form that is most useful to him.

On recent CANDU units or stations, there is an additional seismically qualified control room, well separated from the main control room that contains sufficient controls and equipment to monitor and control the station under shutdown conditions, in the event that the main control room is uninhabitable or unusable.

3. FUTURE CANDU DESIGNS

Recent Canadian experience has identified increasing complexity of operation as an important factor which has a potential impact on safe operations.
Thus future CANDU designs are focusing on an overall reduction in complexity, both in normal operations, and in the mitigation of potential accidents.

Following is a summary of the future directions as described in [8].

3.1 Normal Operation

Priorities for improving nuclear power plant safety in normal operation include:

1. Minimizing the possibility of accident initiation;
2. Reducing occupational dose from normal operation and likely upsets;
3. Reducing routine radioactivity emissions.

3.1.1 Minimize Accident Initiators

The emphasis here is on the simplicity and robustness of the design from the viewpoint of the operators and maintainers. The main steps are to:

a) improve the man-machine interface. This involves both more operator-friendly control centre design, with human factors principles built in from the beginning, and the use of system simplicity and increased automation to make routine operation and maintenance more error-free.

b) simplify system process design and equipment, making use of proven components and lessons learned from operating experience. An example is the layout improvements incorporated in the CANDU 3 design, making the job of environmental qualification of equipment much simpler.

c) improve the engineering processes to take advantage of advances in computer-aided engineering tools and in engineering management techniques. The use of rigorous configuration management gives more assurance that the design will meet its operating requirements in detail. The CANDU 3 has pioneered the use of this approach, by creating a comprehensive CADDS model of the entire plant, giving a database from which drawings and analysis information can be extracted in a controlled manner.

d) design for a comprehensive operating envelope. The previous generation of nuclear power plants was designed primarily for a simple set of "design-basis" operating states. Experience has shown that accidents often occur from less common operating conditions: reduced power, abnormal flux shapes, unusual equipment configurations, etc. Currently,
restrictions posed by plant technical specifications are a source of both production limitations and operational complexity worldwide. Future plant designs must build in larger margins between operating ranges and safety limits, and define comprehensive design envelopes, covering startup, cooldown, maintenance outages, load cycling, etc. For example, the CANDU 3 designs uses core power shaping to limit maximum fuel rating to 20% lower than the design value for the older Bruce A/B design. The CANFLEX fuel bundle now being developed uses graded fuel pin design to further reduce peak fuel rating by 15%. Reduced fuel rating leads to increased thermal margins and lower temperatures during accidents.

Of these four, the man-machine interface has recently received particular attention. Currently the following programmes are under way:

A) Human Factors - In collaboration with Ontario Hydro, a comprehensive human factors program has been developed and is being applied as part of the plant design process. This program ensures that plant designers account for human strengths and weaknesses in every area of the design related to operation, maintenance and station management. The programme includes training designers in ergonomics, providing check lists and anthropometric standards, and performing design reviews focused on operation and maintenance.

B) Strategic Applications of New Digital Systems Technology - A powerful feature of existing CANDU stations is the high degree of automation and the fact that the dynamic plant state is represented in digital computer memory and logic. Exploiting this, designers of recent CANDUs have evolved the human/machine interface to achieve substantial safety and operational benefits. Some of the most significant features and benefits are the following:

• Time for Operators to Think and Plan - In the CANDU 3 design, no operator actions are required for the first 8 hours after any design-basis initiating event, provided safety systems operate as designed. Simple design changes can extend this to 36 hours or more. Even for event sequences where mitigating systems are assumed to fail, the operator is not called on to act in less than 15 minutes. The role of the operator is changing from first-line response to one of verifying the plant's own automatic response.

• Substantial Reduction in Panel Complexity - Many of the fixed indicators and controls have been eliminated from the panels in favour of interactive CRT consoles.
C) Symptom Oriented Emergency Operating Procedures - Recognizing the need for simpler, less event oriented Emergency Operating Procedures - Recognizing the need for simpler, less event oriented Emergency Operating Procedures, a joint task force of CANDU utilities and design organizations is implementing improvements that provide the operator with a short list of critical safety parameters and a methodology to use these parameters to maintain the plant in a safe state regardless of the cause of the original upset.

D) Elimination of Production versus Safety Conflicts - CANDU designers have reviewed operational experience to identify and eliminate instances where operators may face potentially conflicting objectives for safety and production.

E) Provision of On Line Equipment Configuration Control - Starting with the Darlington NGS, a design option provides a computer system and hand-held bar code reading procedure specifiers which dictate and record completion of every "Order to Operate" procedure carried out by station staff. These devices systematically and semi-automatically ensure that the status of 14,000 operational devices in this four-unit station is kept up-to-date and available.

The longer-term development of the advanced control centre includes the following:

- Pattern Recognition
- Operator Decision Support System
- Operation Information System

3.1.2 Reduced Occupational Dose. CANDU reactors have a superb record of low occupational radiation dose, due to such features as on-power refuelling, and low coolant system corrosion and contamination levels. The application of ALARA, and increased public sensitivity to radiation exposure, translate into an impetus towards still lower occupational dose targets, where cost-effective.

In the short-term, the approach is to design for improved atmospheric separation within the reactor building, easier access to equipment for maintenance, and reduced maintenance and equipment replacement requirements. For example, the CANDU 3 reactor building layout and ventilation system are designed so that the entire reactor building, except for the reactor vaults, is accessible on-power, while total occupational exposure will be reduced to 50% of that for existing CANDU 6 reactors.

In the medium- and longer-term, occupational exposure will be reduced by minimizing field maintenance requirements. This can be done by the increased use of automated testing of safety systems, by identifying applications for robotics in maintenance
and inspection activities, and by taking advantage of the benefits of system simplification.

3.1.3 Reduced Routine Emissions. Routine radioactive emissions are very low from today's CANDU reactors, resulting in predicted "fencepost" doses of a few milli-rem per year. Nevertheless, for the same reasons as for occupational exposure, further reduction will be implemented where cost-effective. The eventual goal would be a "self-contained" power plant, with de minimis planned emissions and no requirement for off-site removal of waste products.

In the short-term, pilot studies are under way at Pickering NGS for the permanent storage of low level waste by evaporation followed by immobilization in a solid medium. In the medium term, improvements in tritium removal technology are being pursued, leaving minor noble gas emissions as the main routine release. In the longer term, release of chemicals to the environment will probably become as restricted as release of radionuclides. A first-round study has been done of the changes required to achieve (near) "zero" discharges of both in CANDU. Further and more detailed studies will be undertaken in future.

3.2 Prevent Reactor Damage

To ensure both public perception of safety, and protection of the investment, we must ensure a low likelihood of any event which damages fuel, or which causes major reactor damage. The pressure tube core protects fuel from widespread damage following a failure in a single fuel channel - however the economic consequences of a single channel failure can still be large. In the short term, development work is under way to strengthen the outer calandria tubes of the fuel channels, to provide greater margin to withstand any sudden failure of the inner pressure tube. Further short term development work is aimed at improving fuel integrity margins for more likely events. For example, the core power shaping in the CANDU 3 design improves fuel thermal margins by about 5%. A third major area of work is improved heat sink availability mainly through the addition of high pressure emergency boiler feed (in addition to auxiliary feedwater). This eliminates the need for an operator to quickly depressurize the boilers on total loss of heat sink - a potentially stressful decision.

The design target is that the plant should easily be refurbished following accidents down to the $10^{-4}$ to $10^{-5}$ events per year range, implying limited or zero fuel damage.

In the medium term, the development aim is to reduce the probability of any events leading to fuel damage, even those where damage is restricted to a single channel. Recent developments such as improved detection of incipient leakage in individual channels by increasing the recirculation rate of the
pressure tube/calandria tube annulus gas systems, and addition of redundant backup cooling to fuelling machines are examples of this. In addition, ECC system designs are being adapted to be independent of heat transport pump operation for all pipe breaks, and to increase assurance of fuel integrity for LOCA with coincident AC power failure. This reduces the need to use the moderator as an emergency heat sink; although such an accident would be rare, the recovery cost would be large.

3.3 Protect Pressure Tubes and Contain Releases

The requirement to withstand the dual failure "loss of coolant plus loss of emergency core cooling" has meant in effect demonstrating fuel channel integrity. This is a key element of CANDU safety.

The future direction is to expand the range of events for which pressure-tube integrity is assured. In addition we wish to improve the margins in the analysis - larger margins can lead to a reduced emphasis on in-service testing and licensing-related "burden of proof".

Challenges to pressure-tube integrity derive from fuel overheating due to loss of cooling flow. ECC is, of course, designed to avoid prolonged loss of flow. If the fuel overheats, the pressure tube heats up and, depending on heat transport system pressure, can either strain into contact with the calandria tube (at high pressure, >1 to 2 MPa) or sag into contact (at low pressure, <1 MPa). Very high pressures (>4 to 5 MPa) can lead to non-uniform strain of the pressure-tube and less-predictable pressure-tube behaviour. After pressure tube contact with the calandria tube, heat transfer to the moderator depends largely on the extent of moderator subcooling. Improvements in the margins therefore fall into several areas:

- improved understanding of the phenomena of the event;
- improved capability to provide a channel coolant flow;
- improved capability to depressurize the heat transport system;
- better moderator subcooling margins.

The target for current and new designs is to protect overall channel integrity for the above type of events of frequency greater than $10^{-6}$ per year.

In the short term AECL's objectives are to:

- identify and evaluate analytical conservatisms, especially in the treatment of LOCA, and LOCA with loss of ECC, to better quantify existing margins;
- improve ECC reliability to exceed the 0.999 years/yr. requirement (improved operating margins);
- examine the provision of other sources of makeup water for small breaks as an alternative to ECC;
- assess the capability of automatic heat transport system depressurization for a wider range of events;
- improve moderator subcooling after an accident.

In the medium term, the objectives are to:

- reduce ECC complexity by reducing the number of operating components required, and eliminating operator actions;
- improve the capability of the shutdown cooling system to provide forced-flow cooling for small LOCAs, in addition to its role as a full-pressure/full-temperature heat sink for non-LOCAs.

In the long term, AECL has begun a research programme to develop and prove out a channel which will reject decay heat to the moderator in accidents without pressure tube deformation. One concept under consideration is to fill the gap between the pressure tube and the calandria tube with granules of an oxide. The interspace in the oxide bed would be filled with helium. This design would allow a controlled heat transfer rate to the moderator while providing support to the pressure tube to minimize deformation under accident conditions. Such a channel would allow simplification of ECC and related systems such as heat transport system depressurization.

In the area of containment of gaseous releases, most CANDU units to date have used a high-flow, gravity-fed water dousing system for pressure suppression within containment.

The newest CANDU designs have eliminated this dousing system in favour of a steel-lined containment building constructed to a higher design pressure. This has the advantages of reduced capital cost, reduced operating cost, and superior leak-tightness. For hydrogen control, use of passive catalytic recombiners is an option for new designs; a concept for such units has been developed at the Chalk River Laboratories.

3.4 Protect Calandria

As already noted, the calandria contains the moderator water (which is normally cooled), and is surrounded by shield water, which is also normally cooled. In many ways, this is analogous to the recently-proposed LWR "passive" concepts in which the pressure vessel is immersed in a water pool. The continued cooling of the shield tank water provides a heat sink for severe core damage (confirming molten fuel to a known area).

Even if shield tank cooling is lost, there is a heat sink for many hours (through boiling off the water).
We can capitalize on this existing capability and expand the range of severe accidents which the calandria can arrest, through a better understanding of the physical mechanisms involved.

The calandria and associated internals have always been required to withstand, with margins, a postulated simultaneous pressure-tube/calandria-tube failure. The ability of the calandria to tolerate low-frequency, multi-channel failures is of interest, especially the margins can be increased easily.

A target to protect calandria integrity for individual events of frequency greater than $10^{-7}$ events/year is appropriate in the future.

In the short term, AECL's objectives are to:

- develop an improved analytical understanding of the calandria response to rapid and slow loading (relief capability);
- further assess the inherent capability of the shield tank and end shields to remove decay heat;
- improve the reliability of the moderator cooling system and shield cooling system; and
- examine the benefit of providing additional makeup to the end shields and shield tank.

In the medium term, our objectives are to:

- examine designs which increase the calandria capability to respond in a known fashion to severe accidents involving more than one fuel channel.

For the longer term, AECL has in place a research programme to develop/design the capability for passive moderator cooling. This offers the potential of overall design simplification.

3.5 Mitigate Severe Accidents

Two major accidents in civilian nuclear power plants have focused the attention of the nuclear safety community on the potential for events considered to be very rare. The Three Mile Island accident in 1979 showed that containment will limit the public health consequences very effectively, but that containment integrity could be at risk due to the potential for melt-through or over-pressurization. The Chernobyl accident showed what could happen for an uncontained accident. There were prompt deaths and radiation sickness among plant staff; there could be a small increase in cancer fatalities in the surrounding population; and a large area around the plant was contaminated and will be uninhabited for many years.

These two accidents demonstrate the importance of the containment in limiting the risk to the public. Uncontained accidents are
the only ones with the potential to cause serious off-site contamination or acute health effects. There is an emerging consensus that the predicted frequency of such a "large" release should be less than one per million reactor years. (Both IAEA and EPRI have published this as a target.)

Current CANDU designs can meet this target [9,10,11]. This is primarily because of the low severe core damage frequency (less than $10^{-5}$ per reactor year) and a core-melt progression that is slow-moving. Threats to containment integrity are generally late in time, so that the operator can act to protect containment integrity. Such actions include flooding of the damaged core and restoration of containment integrity are generally late in time, so that the operator can act to protect containment integrity. Such actions include flooding of the damaged core and restoration of containment and shield cooling.

In the short term, the design emphasis for CANDU is on maintaining containment integrity. Steps will include a review of measures to improve the reliability of containment, moderator and shield heat sinks. More detailed study of containment failure modes (including hydrogen burns) for new designs will allow an optimization of the containment design to deal with severe accidents.

In the longer term, implementation of the heat sinks mentioned above in a passive manner should lead to simpler, more reliable systems. In addition we have begun a study to optimize the reactivity characteristics to CANDU from a safety point of view. The study will identify fuel and core concepts for implementation in the longer term which will eliminate or reduce the need for fast, automatic shutdown systems. It is part of the study of advanced fuel cycles for CANDU [12].

4. CONCLUSIONS

CANDU safety design principles are consistent with those established internationally, based on the defense-in-depth approach to ensuring safety.

In addition, because of experience early in the evolution of the CANDU design, CANDU includes features such as separation, diversity, independence and testability for process and safety systems.

CANDU safety design principles have proven themselves to be fundamentally sound. The future direction of CANDU will consider evolution of the design to be progressively simpler to operate, and to be a more robust, forgiving design.
5. REFERENCES


LEVEL 1

High Quality Process Systems
- Low component failure rate
- Tolerant to component failures and human error
  - Redundancy
  - Diversity
  - Fail-Safe
- Control systems with protective capability
- In service inspections

Result
Reliable, Safe Plant Operation

LEVEL 2

Process Failures Beyond Capability of Control System
- LOR
- Loss of boiler feedwater flow (less likely failures)

Safety System Action

Result
Public Safety Maintained
Equipment Damage Prevented

Action of Other Process Systems

LEVEL 3

Severe (Hypothetical) Process Failures
- LOCA (unlikely failures)

Safety System Action
- SDS1 or SDS2
- ECI
- Containment

Result
- Possible Fuel Failures
- Effect on Public Within Limits

FIGURE 1 LEVELS OF SAFETY
HELIUM UNDER HIGH PRESSURE

ELECTROMAGNETIC CLUTCHES

SHUTOFF ROD GUIDE TUBES

SENSORS

MODERATOR

FIGURE 2 REACTOR SHUTDOWN SYSTEMS
FIGURE 3 EMERGENCY COOLANT INJECTION SYSTEM
FIGURE 4 OPERATION OF NEGATIVE PRESSURE CONTAINMENT
FIGURE 5  CANDU 6 NUCLEAR POWER PLANT CONTAINMENT
ABSTRACT

The New Brunswick Power Corporation is a provincially owned utility with a total capacity of 3875 MW. Generation is provided from a mix of sources including coal, oil, and hydraulic as well as a single 680 MW Candu PHWR at Point Lepreau.

Incorporation of the nuclear unit into a smaller utility brought with it a number of administrative and technical challenges. Some of these challenges were unique to the pre-operational design and commissioning period. Others, associated with the need to ensure safe, reliable and economic operation of the facility, remain throughout the operational phase.

Performance of Point Lepreau has been world class since being declared in-service in 1983. The 93.9% capacity factor achieved in the period from the in-service date up to 31 January 1992, has earned Point Lepreau second place in the Nuclear Engineering International ratings. The success of Point Lepreau results from the combination of good design together with a concerted effort to develop programs intended to maintain operational safety and reliability. This approach has been strengthened by the integration of operations, technical, nuclear safety and training resources into one on-site group. A corporate culture has developed which stresses attention to detail, ongoing improvement to the design and, an approach to planning of operations and maintenance activities which includes input from all affected parties.

This paper outlines significant features of the approach adopted at Point Lepreau, summarizes some of the important lessons learned and discusses some challenges which remain.
POINT LEPREAU - A CAPSULE SUMMARY AND HISTORY

Point Lepreau is a single Candu 6 PHWR located on the southern coast of New Brunswick, Canada. The unit went into commercial operation in February 1983 after a construction and commissioning period which began in 1974. It has since operated at high capacity factors.

Incorporation of the single nuclear facility into a smaller utility brought with it a number of administrative and technical challenges. To understand how these challenges were met it is useful to briefly review some of the history.

Shortly after the 1974 decision to construct the facility, a number of decisions were required relating to the timing and/or extent of NB Power involvement in the design, design review and safety analysis phases. Since this represented the Utility's first venture into nuclear generation, no in-house expertise or capability existed.

Clearly, because of NB Power's small size and lack of expertise, primary design responsibility would best remain with Atomic Energy of Canada Limited (AECL) as would the technical responsibility for safety analysis. Sole responsibility for commissioning and subsequent plant operation would be vested with NB Power. In summary, the issue became one of timing with respect to assembly of the commissioning and operations group. A decision was made to assemble this group early; starting in 1975.

Initially a core group was assembled, consisting of existing NB Power staff who already possessed conventional plant experience and supplemented by key personnel hired with relevant experience in nuclear power. The objective of this group was to develop the necessary training, administrative, and operational programs to support the upcoming commissioning and operations phases.

This early assembly of key staff provided the opportunity for a thorough review of, and familiarization with, the plant design. It also allowed for feedback of important operational concerns to be given to the designers. The result was a large number of design improvements which reflected operational considerations. Knowledge acquired by operations staff from this design review process provided a sound technical basis for the commissioning program and for production of the operating documentation. An intangible, and extremely important, benefit from this effort was the degree of understanding and strong sense of "ownership" in the design.

An important factor in enhancing operational safety was the inclusion, in the commissioning/operations group, of personnel who were experienced in licensing and safety analysis. In effect knowledge of three aspects of the station's life cycle; design, operation, and regulation were brought together in one group. This has fostered a safety awareness among station staff.
This safety awareness is the result of firsthand knowledge and involvement in the complex and often esoteric issues associated with reactor safety and licensing, particularly those related to

- procurement and maintenance of the reactor operating licence and the associated incident assessment and reporting requirements,

- the complexities associated with definition of the allowable operating envelope as defined by the plant design and safety analysis,

- the need for feedback of operational knowledge and practices into the ongoing safety analysis program necessary to maintain the reactor operating licence current, and,

- the importance of operational feedback to the design process.

LONG TERM STRATEGY

The establishment and maintenance of a long term strategy is significant in the successful incorporation of a relatively large and complex unit such as the Candu 6 into a smaller utility. This strategy must include a management culture which encourages a longer term perspective be maintained when addressing day-to-day operational problems. Such problems must be assessed for their potential impact on long term viability, safety and reliability. Emphasis must be placed on development of the appropriate programs to address issues with potential negative impact on these areas. The management style must be receptive to accepting short term penalties when it is necessary to "do it correctly and thoroughly the first time".

This methodology also requires that potential contributions to unavailability be identified and carefully examined, exhaustive efforts be made to eliminate or account for uncertainties and effective preventative maintenance programs be developed where necessary.

An example of this strategy can be found in the pressure tube program developed for Point Lepreau. When the Canadian nuclear industry first became aware that pressure tubes were subject to a number of phenomena which reduced their design life expectancy, the importance of this issue to Point Lepreau operational safety and reliability was immediately recognized. Staff from the station became active participants in the pressure tube research and development work being undertaken under the aegis of the Candu Owners Group (COG). This involvement provided information of direct applicability to plant operation and allowed early decisions to be made to maximize pressure tube longevity.
As a result, a long term plan was developed in 1987. The strategy in this plan remains valid today. The plan accounts for identified uncertainties such as the rate of deuterium pick-up in the pressure tubes and includes activities to reduce or eliminate these uncertainties. The plan identifies work to be performed as part of the ongoing reactor maintenance program for the remainder of the reactor life. In this way operational safety and reliability can be maintained at the highest level.

UNDERSTANDING OF FUNDAMENTALS

Since station staff essentially have responsibility for all aspects of NB Power's nuclear program, their involvement extends beyond day to day operational issues. These broader responsibilities include

- active participation in COG R&D programs aimed at improving knowledge in issues related to both safety & licensing and Candu technology,

- development of strategies to address all generic and plant specific Action Items raised by the Atomic Energy Control Board (AECB),

- development and maintenance of training programs to meet station objectives and the training requirements established by the AECB for those staff requiring AECB authorization and,

- development of a utility response to proposed changes in regulatory policy.

This exposure gives staff a broader knowledge of issues and provides access to a wider range of expertise. When coupled with responsibility for the design and the requirement for a long term strategy in all significant issues, station staff have the motivation and access to the knowledge and expertise necessary to develop a more fundamental understanding of issues as they arise.

Earlier discussion emphasized the need for long term planning. While it may be adequate, in the short term, to address only the symptoms of an operational problem, longer term solutions may ultimately be required. A more fundamental understanding contributes to a better definition of the necessary steps to fully resolve the issue.

As an example, to demonstrate that the integrity of the Point Lepreau containment envelope is being maintained, pressure tests are required to be performed at periodic intervals. Early results from these tests indicated that the leakage from containment was increasing. A long term program was required to address this issue. Such a program was developed which contained short and
long term elements to address all issues related to containment integrity including

i) safety analysis to demonstrate that large margins existed between the actual leak rates being measured in the periodic tests and those rates which would be of concern in relation to AECB Siting Guidelines should a design basis accident occur,

ii) review of test results which identified the cause of increased leakage to be age related degradation of the original containment liner material,

iii) research and development aimed at qualification of an improved containment liner material,

iv) development of methods for application of the new liner material which addressed the potential health hazards associated with its chemical constituents,

v) development of an on-line containment integrity test aimed at demonstrating containment integrity with the reactor operating, and,

vi) development of an improved and standardized method of performing Containment full pressure tests.

As a result, it was demonstrated that actual leak rates measured in earlier tests, although higher than that assumed in design and safety analysis, were at least an order of magnitude lower than that which would present any safety concern.

Nevertheless a new liner material was developed and qualified. Implementation of an ongoing program to apply the new material has reduced the leak rates to values similar to those measured before plant start-up.

Development of the on-line containment integrity test has been completed and has extended the period between periodic full pressure tests. These full pressure tests require five days of plant outage to perform.

This long term program has therefore;

- improved the understanding of a variety of issues related to containment performance,

- assured that the potential impact on plant production has been minimized, and,

- provided the necessary demonstration and assurance of continued containment integrity.
OPERATIONAL SAFETY ENHANCEMENT

Once the operational phase was entered, two major changes occurred; responsibility for the maintenance of, as well as any improvements to, the plant design were transferred to NB Power and the need for ongoing licensing and safety analysis support was recognized.

Due to the small size of the utility and the fact that there is only a single nuclear unit, responsibility for this ongoing support has remained with the operations staff at the site. This approach has been strengthened by the vast body of knowledge and experience gained during the pre-operational (design review) phase, commissioning, and the first years of operation.

An approach to plant operation has evolved that includes particular emphasis on several key components. These include the following.

Design Improvement

The familiarity with the design and the beneficial experience resulting from design changes during commissioning has been carried over into the operational phase. Emphasis continues to be placed on identification of problem areas and the development of design improvements and/or related programs to solve them. Simply coping with unsatisfactory symptoms continues to be actively discouraged. This approach has lead to the implementation of nearly 2500 design changes to date.

The manner by which a design change is proposed and subsequently reviewed, approved and implemented is under the direct control of site staff. A review procedure, which involves operational and technical staff, is followed which assures that any impact on systems and plant operation is identified and assessed. In addition, all changes to plant documentation which are necessary to assure that configuration control is maintained are identified and prepared before the design change is implemented. Safety and licensing staff input is sought to assess any impact on plant safety analysis, the operating licence and related documentation as well as to identify the need for external review and approval which may be required prior to implementing the proposed change.

The design change process is enhanced by the direct involvement of all affected groups. Since these staff are all present at site, communication amongst them is fostered.
Operational Support

Several notable features have come to exist as a result of a corporate culture which stresses excellence in operations.

An emphasis has been placed on detailed work planning whenever maintenance or modification activities are required on plant systems. The procedure followed during preparation of these plans includes a requirement for review by the operations group before the plan is issued. In addition to obtaining valuable operational feedback, this assures dialogue is maintained between the operations and technical groups.

The close proximity to plant operation achieved by location of all technical support staff at the station has also fostered a constructive and collaborative approach to production and maintenance of operating documentation. Production of operational documentation has always included a review by senior operational staff before it is issued.

This operational document production and review process has been found to provide two benefits:

i) constructive operational feedback is incorporated into the procedures which has lead to better quality documents, and,

ii) through discussion with technical staff, the operating staff become more familiar with design requirements, system and equipment capabilities and the basis for the operating envelope.

Where necessary this process also includes a review by the nuclear safety and licensing groups. Again, this fosters an awareness of the safety design features, any limitations to assure operation within the analyzed envelope and the basis for these operational constraints. This promotes a safety culture amongst operational and technical support staff.

LESSONS LEARNED

Maintenance Support

As noted earlier, one of the major thrusts adopted during early operation stressed excellence in operations. This included emphasis on the quality of operational documentation, operational review of work plans and operator training. With time, experience gained from maintenance activities indicated that similar emphasis and rigour was required in support for maintenance activities. This required increased technical involvement in preparation of maintenance procedures, recognition of the need maintaining a safety culture amongst trades staff, development of
Root Cause Determination

Over time, a weakness became evident in the approach adopted when identifying follow-up actions from unplanned events. This weakness resulted from a lack of focus on root cause determination. It had resulted in identification of a myriad of follow-up actions. This in turn produced a growing backlog of actions. Effectiveness in implementing the actions in a timely manner was reduced. The system was becoming bogged down.

As a result the process of review of unplanned events was revised. It now culminates in a meeting of staff from production, technical and management groups. The emphasis during this meeting is to reach agreement on the root cause of the event and identify those follow-up actions necessary to address the identified root cause. This new approach has proven effective. In addition, the actions are better defined and understood since the parties who will be required to complete the follow-up are now directly involved.

Integration of Design and Safety Analysis into Operation

The phases of a nuclear plant's life cycle have been identified, in simplistic form, in Figure 1. In the case of Point Lepreau, operational staff involvement began with an extensive design review exercise and carried through commissioning to the operational phase. As discussed earlier, feedback to the designer provided during the design review phase was extremely beneficial in improving the reliability and operability of the facility.

What was missed, however, was a full appreciation of the potential importance, on plant operation, of subtleties in the design requirements and safety analysis assumptions.

For any nuclear plant, emphasis must be placed on the specification of the operational envelope, as defined in the design requirements and safety analysis. This operational envelope forms the framework within which day to day operation must be maintained in order to assure the design and safety analysis is valid.

Specification of the operating envelope is a complex and difficult task. It spans major and evolutionary phases of the plants life cycle (Figure 1) and involves a wide variety of specialized expertise. Ideally it also requires knowledge and understanding of details, limitations and capabilities of the myriad of equipment and systems which make up the facility as
well as how they are to be operated. The degree of efficiency and success which is achieved in adequately specifying the operating envelope is clearly dependent upon the extent of cooperation and communication between the various parties.

The communication of equipment and systems performance assumptions and specifications must be clear and unambiguous to all involved parties. For example it is common during performance of safety analysis to make assumptions with regard to the maximum deviation of various parameters (from their design centre values) which should be allowed during plant operation. The capability to operate the plant within the operational envelope would be compromised if;

- the designer has not provided the capability to accurately monitor the parameter within the assumed tolerance or,

- the operator was not made aware of the requirement to monitor the particular parameter and maintain it within the specified limits.

Experience at Point Lepreau, has revealed that the required communication between the phases of the life cycle was less than optimum.

**AN EXAMPLE**

Discussion in the previous section emphasized the need to properly identify and specify design requirements. The following example is provided to better illustrate one of the potential outcomes stemming from improper or inadequate specification of these requirements.

The example chosen discusses an incident involving the speed of response of instrumentation in the high moderator temperature trip circuitry of Shutdown System 1. In this example, the actual speed of response was found to be slower than the value used in the original design information.

The high moderator temperature trip parameter had been a retrofit to Shutdown System 1, completed in 1986, in response to a licensing issue. The retrofit consisted of triplicated Resistance Temperature Detectors (RTDs) strapped onto the moderator piping at the exit from the calandria. Should a loss of service water occur, a rising moderator temperature would result and be sensed by these RTDs. A reactor trip would then be initiated.

The performance characteristics of the RTDs had not been well specified as part of the design. The response time of the RTD had been determined by placing it in contact with a hot pipe, under laboratory conditions. This was a non-representative test in that it did not correctly account for all of the thermal lags which
would be inherent in the actual field application. Nevertheless the results of this test formed the basis for design and safety analysis assessments. The response time of the RTDs as specified in the design manual, was based upon the laboratory test results. No emphasis was placed on the sensitivity of the trip (or lack thereof) to the RTD response time. Similarly, no requirements to verify it as part of commissioning tests were specified.

In 1989, unexpected anomalous response of one of the three temperature measurement loops was noted following a duty changeover of the local air coolers in the room containing the RTDs. The response was first thought to be an artifact of the local air flows in the vicinity of the RTDs. However, an operational test was developed and performed which involved a moderator temperature manoeuvre. The test results showed that the actual time constant was longer than that measured in the laboratory test (i.e. the value specified in the design manual and subsequently used in the safety analysis). As a result of this discrepancy, an interim measure was taken to reduce the setpoint of the moderator high temperature trip. This action compensated for the longer time constant. Detailed safety analysis was performed to assess the effect of the longer time constant. This work clearly demonstrated that the effect was negligible.

However, since the response of the RTDs was different, and in a less conservative direction than that specified in the design, current AECB rules for evaluating safety system performance required that SDS1 be reported as having been completely unavailable. These rules also stipulated that the period of unavailability existed from the time when the trip had been first installed, in 1986, until the compensating setpoint reduction had been performed in 1989!!

The event emphasizes the importance of correctly specifying performance expectations in the design and safety analysis phases of a plant's life. These specifications can then be verified, where necessary, during commissioning. If degradation can occur during operation, meaningful operational tests can be developed and performed periodically to monitor for any reduction in performance.

CHALLENGES REMAINING

In order to adequately define the allowable operational envelope, a program has been initiated at Point Lepreau to review rigorously the design and associated safety analysis. The objective of this program is to review the existing design, compare it with assumptions used in the safety analysis, and document the resulting information. This then forms the basis for a rigorous definition of the allowable operating envelope. Details of the scope of this program are contained in
Reference 1. The challenge will be to complete this program and effectively integrate the results into operational documentation.

Secondly, recent experience with the existing requirements for reporting the reliability performance of special safety systems has been unsatisfactory. For example, this method assumes that systems were designed properly and that design requirements were adequately specified to assure demonstration in the commissioning phase. This weakness has been recognized by the industry for some time (Reference 2). However no progress has been made to find an improved methodology.

The moderator temperature trip example cited in this paper illustrates how an inadequate basis for, and poor communication of, the performance expectations of equipment and systems has lead to the implication that Shutdown System 1 performance is poor. The safety significance of the example event was in fact negligible, despite the apparent complete unavailability of the system as portrayed by the current methodology of reporting unavailability.

In fact the current reporting system penalizes the operator for critically reviewing design and safety analysis. A more logically derived method of reporting is required which;

- provides a broader assessment of the safety significance of events,
- includes a performance indicator which monitors adequacy of operations and maintenance activities, and,
- includes a measure of the robustness of the design, construction and commissioning phases of a plants life cycle and hence provides a clear mechanism of feedback to cater to any inherent weakness.

Such an indicator also has the advantage that public perception is enhanced by the proper representation of the risk to plant and public safety which may result from any event.

Finally, there is the issue of maintaining and strengthening the existing safety culture. This is particularly of concern when new staff are employed. New staff do not have the benefit of experience gained during design review, commissioning and early operation. This experience had resulted in a sound understanding of the design requirements and operational capabilities together with an associated safety awareness. Consequently emphasis must be placed on development of this awareness with less reliance on experience as the primary method of providing it.
SUMMARY

The New Brunswick Power Corporation has successfully integrated a relatively large nuclear unit into a small utility. The unit has operated with a high degree of safety and reliability over the first ten years. Some of this success results from the requirements and the benefits of a smaller utility. These include; the need to set long term goals; a stronger sense of ownership in the facility and its performance; the enhanced teamwork and group interaction which comes from having operational and supporting staff organized within one group located at the site; and finally, the broader responsibility assigned to the site staff.

REFERENCES


2. Inter-organizational Working Group, "Proposed Safety Requirements for Licensing of Candu Nuclear Power Plants", AECB INFO-1149, November 1978
FIGURE 1: SIMPLIFIED NUCLEAR PLANT LIFE CYCLE
ADVANCES IN CANADIAN REGULATORY PRACTICE

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Abstract

The new General Amendments to the Regulations, new recommendations on dose limits, developments in techniques and safety thinking, and aging of plant are all contributing to the need for a significant number of new regulatory documents on a wide range of topics.

This paper highlights a number of initiatives taken in response to these pressures, giving a brief background to the initiative and, where possible, outlines some of the ideas in the document being written and current progress. The paper deals with licensing guides on new dose limits, dosimetry, safety analysis, reliability, fault tree analysis, reporting requirements, human factors, software, the ALARA principle, backfitting and the licensing process.

1. INTRODUCTION

A number of new regulations, regulatory guides and policy documents are in preparation at the AECB. Some are initiatives that have been around for some years and are being reactivated; some are new. Some of them will affect only one sector of the nuclear industry; two at least will affect all. This paper outlines a number of the more interesting or controversial ones. In all cases, the Board will be following its standard practice of consultation with the public and industry through the Consultative Document process, and also where new regulations are contemplated, through the public consultation process required under the Government's policies embodied in "Citizens' Code of Regulatory Fairness".

2. NEW DOSE LIMITS (C-122)

In 1991 the International Commission on Radiological Protection (ICRP) published new recommendations on radiation dose limits for both the public and workers. The AECB staff and the Board's Advisory Committee on Radiological Protection have reviewed the ICRP's recommendations, and the Board proposes to incorporate them, or their intent, into the Regulations as soon as possible. The following tables compare the current dose limits, the limits proposed in the General Amendments which were published in the
Canada Gazette, Part 1,\(^{(5)}\), and those proposed in Consultative Document C-122\(^{(6)}\).

### Table 1
**STOCHASTIC DOSE LIMITS (mSv)**

<table>
<thead>
<tr>
<th>EXPOSED POPULATION</th>
<th>CURRENT REGULATIONS &amp; GENERAL AMENDMENTS</th>
<th>C-122</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WORKERS:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Limit</td>
<td>50</td>
<td>20</td>
</tr>
<tr>
<td>Quarterly Limit</td>
<td>30</td>
<td>None</td>
</tr>
<tr>
<td><strong>PUBLIC:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual Limit</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><strong>FOETAL:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Remainder of Term</td>
<td>10 mSv</td>
<td>2mSv (abdomen) + 1/20ALI</td>
</tr>
<tr>
<td></td>
<td>0.6 mSv per 2 weeks</td>
<td>(foetal dose: 1 mSv external + 1 mSv internal)</td>
</tr>
</tbody>
</table>

### Table 2
**DETERMINISTIC DOSE LIMITS (mSv)**

<table>
<thead>
<tr>
<th>ORGAN</th>
<th>CURRENT</th>
<th>GENERAL AMENDMENTS</th>
<th>C-122</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Quarterly</td>
<td>Annual</td>
<td>Quarterly</td>
</tr>
<tr>
<td><strong>Lens of the eye</strong></td>
<td>Workers</td>
<td>80</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>-</td>
<td>15</td>
</tr>
<tr>
<td><strong>Skin</strong></td>
<td>Workers</td>
<td>150</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>-</td>
<td>30</td>
</tr>
<tr>
<td><strong>Hands and Feet</strong></td>
<td>Workers</td>
<td>380</td>
<td>750</td>
</tr>
<tr>
<td></td>
<td>Public</td>
<td>-</td>
<td>75</td>
</tr>
</tbody>
</table>

*The General Amendments specify a limit only for "any other organ or tissue".*
published two consultative documents relating to the subject of dosimetry: C-92, a policy statement dealing with who may perform dosimetry services, and C-106, a specification of technical and quality assurance criteria to be met by dosimetry operators. At the moment, there are relatively few such operators at present in Canada.

You may recall, however, that in the last federal budget the government announced that it would be seeking a private purchaser for the service, which has been operated since 1951 by Health and Welfare Canada. Private operators have already informed the AECB that they wish to offer such services. The AECB believes that private dosimetry services should be approved by the AECB and be subject to appropriate QA standards. We are therefore developing a certification process for dosimetry service operations, and a guideline will be published this year on this subject. We will also be revising C-106 and C-92 to clarify what standards will be sought from all operators, both private and public.

4. SAFETY ANALYSIS FOR POWER PLANTS (C-6)

Consultative Document C-6 was first published in 1980, and was a first attempt at using a more sophisticated approach than the "single-dual failure" approach used in the Siting Guide, which was the basis for licensing Douglas Point, Pickering, Bruce and the 600 MW plants.

C-6 was used on a trial basis to license Darlington Nuclear Generating Station. At a workshop in October 1990, the results of that "trial basis" were reviewed by representatives from Ontario Hydro, AECL, Hydro-Québec, New Brunswick Power, and the AECB, with an observer from the Board’s Advisory Committee on Nuclear Safety, in preparation for a review and rewrite of this document.

The general consensus of the workshop was that C-6 was a practical guide for safety analysis, and had resulted in improvements in safety analysis. However, it required clarification in some key areas, and negotiated improvements in several others.

Some of the points made at the workshop were:

1) An "upper tier" document is needed to state the general nuclear safety requirements.

2) The purpose of C-6 needs to be more clearly stated.

3) The use of dose limits for judging events below a specified low frequency should be examined.
In essence, the new limits in C-122 require a reduction in the public dose limit from 5 mSv to 1 mSv per annum, and from 50 to 20 mSv per annum for atomic radiation workers. The latter is slightly more restrictive than the ICRP recommendations, which propose that workers should be restricted to 100 mSv over a 5-year period, with no more than 50 mSv in any one year. We proposed a straight limit of 20 mSv for two reasons: 1) we wish to put pressure on licensees to improve their control of doses so that workers would not be subject to higher than average doses for two years, and then risk being laid off or reassigned to less responsible positions, and 2) we expect the ICRP will change its recommendation to 20 mSv/year in the near future.

We have received many comments on the proposed new limits. The major concerns were expressed by the mining industry and the nuclear medicine industry. The mining industry believes it will be very difficult and expensive to meet a limit 20 mSv/year (particularly for its face workers) and insists it needs the flexibility inherent in ICRP's original recommendations. Ontario Hydro also believes the 100 mSv/5 years is preferable, as it will give more flexibility when planning such activities as re-tubing. The nuclear medicine industry is particularly concerned with the proposed limits for Atomic Radiation Workers who become pregnant, as the limit is set to be more restrictive to the fetus than to the mother. In small hospitals and institutions, this may result in the woman being laid off, as alternative employment during the term of the pregnancy may not exist.

The AECB is taking all the comments very seriously and will be making changes to the proposed limits as a result. All those who responded to the consultative document and to a questionnaire designed to identify the financial impact of the proposals on the industry will be receiving a letter this month outlining the changes the AECB proposes as a result of the comments received. One change being considered is a proposal for a 5-year limit on dose of 100 mSv for ARWs, together with a limit in any one year of 50 mSv, as recommended by ICRP. We will be seeking further advice from hospital staff on solutions to the difficulties the new recommendations impose on pregnant women.

Following this "disposition" letter, we expect to publish a revision of the proposed regulations in late fall 1992. Note that proposed "coming into force" date for dose limits for ARWs is 1995, and 1993 for the public doses.

3. DOSIMETRY (C-92 and C-106)

Lower dose limits increase the need to be sure that the number quoted for a dose can be relied on, since the chance of an overexposure will likely increase. A reliable measure of doses is a problem of particular concern for uranium miners. The AECB is therefore examining the whole question of dosimetry and the measuring and assigning of doses to individuals. The AECB has
4) The list of events to be analyzed in Table 1 of C-6 is too design-specific, and a better method of classifying events needs to be found.

5) Some of the deterministic rules, such as crediting process system actions, were not consistent with the concept of frequency-based classification.

6) The reasons for analyzing non-design basis events need clarification.

7) The objectives of the systematic design review need clarification.

8) The role of Probabilistic Risk Assessment (PRA) needs clarification.

Our experience with the application of C-6 to CANDU 3 reinforces these and other conclusions from the workshop. C-6 was a confusing document to many, as it appeared to be neither fish nor fowl -- it was not clear if it was intended to be probabilistic or deterministic in nature.

The answer is that it was both. In essence, C-6 calls for:

1) A systematic design review to identify what failures can lead to release of radioactive material to the environment, [para 3.2(a) of C-6].

2) A distillation of the results of this review into "events that should be analyzed" [paras 3.2(b), (c) and (d)], i.e., those events which may set performance requirements for systems which are required to prevent or mitigate the effects of process system failures.

3) Analysis of a predetermined table of events, and of those events arising from 2) above which were not already in the table.

4) Safety analysis to be done using the conservative principles and practices outlined in Section 4.

5) Acceptance criteria for these conservative analyses. (The Class/Consequence Table given in Table 2 of C-6.)

The "probabilistic" part of C-6 is the exercise called for in 1) and 2) above -- although "probabilistic" is a poor word to use for the process. The intent is that, in satisfying para 3.2(a), the systematic design review should analyse the design of the plant as it really is. In other words it was intended that there would be no arbitrary conservatism in the systematic review, as conservatism has no place in this type of exercise. Conservatism does have a place in distilling the results into "events to be analyzed" -- and conservatism in the safety analysis itself.
(i.e., demonstration that dose limits are met) is mandated. It is the safety analysis in sections 4 and 5 of C-6, then, that remains "deterministic".

From the discussions in October 1990, it was clear many users had divined the AECB's intentions -- and made it equally clear they should not have had to divine it! C-6 is now being rewritten using the results of the workshop. In particular, the rewrite should result in a much clearer document. A number of controversies still need to be resolved. Should the document include a predefined table of events to be analyzed? Should the systematic design review be the starting point of a Probabilistic Risk Assessment, which would be completed as the design is completed? What is the role of Probabilistic Risk Assessment in the licensing process and how should it be included in C-6? Should we require an "uncertainty analysis" for PRA? What should be the requirements for Quality Assurance in safety analysis? How can we ensure better configuration control between safety analysis and the plant state? What should the document say about Minimum Allowable Performance Standards, (MAPS) and how should they be derived from the safety analysis?

These, and other questions, are under active discussion within the AECB, and we will be seeking industry's views on these questions as the document is written. The preparation of the revised C-6 has been delayed by nearly a year as a result of the Darlington fuel failure problem. Our current plan is to produce a draft for detailed discussion with industry in the fall of this year.

5. RELIABILITY (C-98)

A licensing guide on reliability requirements for power plants has been in gestation for ten years. Part of the difficulty in producing a technically sound document in this area has been the Board's own historical requirements to demonstrate the time unavailability of special safety systems. What the public (and hence the regulator) is interested in, is how safe is a nuclear facility going to be in the future. The past is of interest only insofar as it is capable of telling us about what might occur in the future. In reliability terms, this translates into a need to know what the likelihood is, that in the future, a safety system will meet its required specification when called upon to do so. This was, in fact, the intent of the 1965 papers written by G.C. Laurence. For practical reasons, this has been interpreted in operation as "how many hours in a year was a safety system unavailable" -- and this is the measure that has been used by the AECB as an indicator of satisfactory performance for many years.

There are some significant difficulties with this practical measure. Table 3 quotes past unavailability of safety systems at a typical, well-run Canadian power plant over a 6-year period.
Table 3
Actual Past Unavailabilities

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>SDS1</td>
<td>0.00</td>
<td>0.64</td>
<td>1.00</td>
<td>1.00</td>
<td>0.22</td>
<td>0.00</td>
<td>1.0x10^-3</td>
</tr>
<tr>
<td>SDS2</td>
<td>0.00</td>
<td>2.9x10^-7</td>
<td>7.6x10^-6</td>
<td>0.00</td>
<td>2.3x10^-4</td>
<td>0.00</td>
<td>1.0x10^-3</td>
</tr>
<tr>
<td>ECC</td>
<td>9.5x10^-4</td>
<td>3.4x10^-4</td>
<td>0.00</td>
<td>3.9x10^-2</td>
<td>8.9x10^-5</td>
<td>0.00</td>
<td>4.3x10^-3</td>
</tr>
<tr>
<td>CONT</td>
<td>3.0x10^-4</td>
<td>8.2x10^-6</td>
<td>0.00</td>
<td>1.2x10^-4</td>
<td>0.13</td>
<td>0.00</td>
<td>1.0x10^-3</td>
</tr>
</tbody>
</table>

First, note that the unavailabilities vary by more than five orders of magnitude. Second, note we have not shut that plant down! Third, whenever a problem is encountered, it is fixed, since the utility is well run. Fourth, translating this information into a "predicted future unavailability" is difficult, and requires an analysis which can be readily compared with observed failure modes and failure rates. To quote the Inter-Organizational Working Group(15) "seldom does a failure render a system completely unavailable, but some failures are reported as a total unavailability, even though system capacity may have suffered only a small decrease. Care must therefore be exercised in interpretation of such information."

Let us examine how "unsafe fault types" are currently classified and reported. Table 4 lists the definitions of Fault Types 1 to 3 which are typical of those used by licensees.

The basic definition for Type 1 failures clearly represents a system unavailability. However, in practice, failures of one process trip parameter have been classified as Type 1 failures, even though the sensors for other parameters are available. In reality, these failures represent a loss of redundancy (which will affect reliability) but in fact do not make the system unavailable since the design specification can still be satisfied. On the other hand, Type 3 failures, which are currently ignored in terms of unavailability, also represent a loss of redundancy and hence will reduce reliability.
<table>
<thead>
<tr>
<th>TYPE</th>
<th>DEFINITION</th>
<th>CURRENTLY REPORTED AS:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System is completely ineffective against one or more of design basis events. Might still provide full protection for some events. (Traditionally has been taken to mean one process trip parameter is impaired even though other parameter may be available.)</td>
<td>System unavailable</td>
</tr>
<tr>
<td>2</td>
<td>Significant reduction in effectiveness of the system, such that it would fail to meet its design objectives. Provides some protection for all applicable events and significant benefit would be gained from its operation. (Generally applies to failures where component timing or accuracy is outside of its design requirements.)</td>
<td>System unavailable</td>
</tr>
<tr>
<td>3</td>
<td>Reduces the redundancy of the system. The system would still meet its design requirements. (Components are all included in Test Frequency Studies.)</td>
<td>Not reported as unavailability</td>
</tr>
</tbody>
</table>

We conclude that the current classification scheme for reporting faults overemphasizes the importance of some failure modes, as far as reliability goes, and ignores others completely; it also de-emphasizes the importance of using maintenance data obtained in operation to validate reliability predictions. Current AECB requirements have resulted in inadequate emphasis on the need for good predictions of reliability, ignored mission time (particularly important for ECC and Containment) and overemphasized the importance of testing, to the point where testing can result in a reduction in reliability due to wear out of components, and a too complex design.

A new version of C-98, Requirements for Reliability Analysis is being written to correct this situation. The new version starts by proposing that, for licensing purposes, the definition of reliability for special safety systems should be changed from the current "time unavailability" to:

"The probability that a system will meet its minimum performance specification when called upon to do so."
It is the AECB's intent to require reliability targets to be specified for all other safety related systems. The measure of reliability to be used for these systems will be left to the designer and licensees to choose. The most appropriate measure depends on the task required of the system. "Time availability", as a reliability measure, is for example, very appropriate for a system such as electrical power which has to be supplied with a very low probability of being interrupted. The degree of reliability that should be achieved we believe should be derived by the licensee from PRA type analyses.

The new version will also lay much greater stress on careful definition of specified performance. The design intent should be re-cast as a specified performance which will have to be defined in hard physical terms (Mg of water/sec; minimum pressure or temperature; litres of water in a tank, etc.). Within the system boundaries, the effects of testing circuits and built-in redundancy on reliability will need to be examined. The effects of external influences, such as the degree of independence actually achieved, and the role of supporting systems should be evaluated.

We see this proposed Regulatory Guide as a significant step; we will be seeking input from designers and operators during the development of the document at an earlier stage than has been our usual practice before - that is, in parallel with internal AECB staff discussions. Some licensees are already moving in a direction we believe is consistent with these proposals. The draft which will be used as a basis for discussion with interested people should be available this summer.

6. FAULT TREE ANALYSIS (C-70)

We have found it difficult to review many of the fault trees submitted to us, simply because they vary so widely in standard of presentation, and degree of concordance between the logic of the trees and the systems that are being modelled. C-70\(^{(17)}\) defines standards that should be followed should a licensee choose to use this method of analysis for any purpose. It is not the AECB's intention to require fault trees to be used -- that is the proponent's decision. However, if a proponent does wish to use the technique, we would like to be able to read, review and audit the result.

We would like to get users' comments on this document in parallel with our internal review as well, since it is intended to assist both the preparation and the review of fault trees. The first draft is completed, and will be available for comment in the next month or so.
Consultative Document C-99, a proposed policy statement on reporting requirements for operating nuclear power plants, was issued for comment on September 9, 1991. Its purpose is to consolidate the reporting requirements of reactor operating licences in a single document. At present, operating licences contain conditions that require prompt reporting of events in specified classes as well as routine reports (annual or quarterly) of operating information. In addition, the Regulations require prompt reporting of events such as loss or theft of prescribed substances and radiation overexposures. However, the requirements for the content and timing of event reports have been spelled out in correspondence between AECB staff and licensees, rather than in the licences themselves. Discussions between AECB staff and licensees have led to agreements on both immediate oral reporting of events and on subsequent written reporting of these events. Although these have been broadly consistent, there have been some differences that have developed over the years, in the reporting practices at various licensed facilities. Consultative Document C-99 was intended to codify a consistent set of reporting requirements for all licensed power reactor facilities. It includes definitions of what has to be reported, the required timing of the reports, and the required contents of the reports.

Although the proposed requirements in Consultative Document C-99 are largely a consolidation of current requirements and practices, the number of operating events that would require prompt reporting has increased. The classes of event that we propose to add to the list are those that we consider to be possible "near miss" or "precursor" events. We believe that operating experience, both in Canada and abroad, clearly shows the value of a process for systematic assessment and reporting of events which may be a precursor of a serious problem. The objective is to ensure timely corrective action that will prevent more serious events from occurring. In trying to include "near miss" events in our list of reportable events we were, of course, aware that it is difficult, if not impossible, to come up with a definition of a "near miss" that will be universally accepted. Thus, we were not surprised that this aspect of Consultative Document C-99 drew much negative comment from our licensees.

We have received comments on the proposed policy statement from all three Canadian utilities operating nuclear power plants and from one member of the public. The major comments made by the utilities were that the proposed policy statement was too detailed and would greatly expand reporting requirements. Some comments suggested that implementing the proposed policy would mask real safety issues and divert resources from other activities more important to safety. Utility representatives recommended that the proposed policy statement limit itself to enunciating broad principles and objectives and allow the utilities more flexibility to decide how to meet the
requirements. By contrast, the only comment received from outside the industry suggested that the proposed policy be even more prescriptive, requiring the use of a standard format for event reports. This was because the commenter believes that current reports are of limited value because of inconsistencies in report content and detail.

We are now reviewing the comments received and deciding on possible changes to Consultative Document C-99. The changes are likely to be of four kinds:

1) A better explanation of the reasons for a proposed requirement, where this has clearly been misunderstood.

2) Improved wording to more clearly define what is wanted. The current wording of some sections was interpreted by licensees as requiring more than was intended. Our licensees also pointed out, and we agree, that the criteria for determining if an event requires prompt reporting need to be made more specific.

3) Deletion of some requirements. For example, the current version requires that specific data be included in the licensees' quarterly reports. These are data that we use in our assessments of licence performance. They include, for example, data that could indicate maintenance backlogs. The licensees have also pointed out that they can furnish this data in various ways and that they should not be required, as a condition of their licences, to use a particular reporting format. We agree.

4) Increased emphasis on human factors reporting.

8. HUMAN FACTORS (C-119)

Human factors is a discipline that generates knowledge about the functional capabilities and limitations of human beings, and applies this knowledge to the design, construction, staffing, operation, maintenance and testing of systems that employ both technology and people in an interactive process. It is a relatively new area of work that is multi-disciplinary in nature, and its knowledge and methods are used in a very wide variety of applications.

It is clear to everybody that, if a nuclear reactor is to produce electricity safely, it requires not just that its hardware is designed and operated well, but also that the whole of the organization that runs it must operate well. A precise coordination of a large number of human and mechanical elements is needed to do this. From a human factors point of view, a reactor can be viewed as a complex "socio-technical system". This idea is not new, but its implications are only partly understood. After TMI-2, there was an almost exclusive concern
with errors in the observable behaviour of people - that is in their manipulative skills. This can be illustrated in a number of ways. Assessment of human reliability focussed almost entirely on developing predictions of operator error as a function of time after an accident has occurred (e.g. the model used in Safety Design Matrices and elsewhere). Human factors specialists who were hired into the nuclear industry (particularly in the USA) focussed largely on improving control room design and operator training methods, i.e. on the operator/system interface. On the other hand, few constructive programs were put in place to examine the part played by the operators' mental model of the plant and what errors of diagnosis or operating strategy might result from that model. This was despite the conclusion that deficiencies in these mental models played a large part in the TMI accident. Further, the part that managerial, organizational and regulatory deficiencies play in causing events has still not been addressed, except to make many references to the need for a "safety culture".

The AECB is convinced that regulatory initiatives must be taken in this area. We believe that a knowledge of human factors is essential in carrying out design, construction, operation, testing, maintenance and management of a nuclear facility. Effective application of that knowledge can only be achieved if it is integrated into the designers' and the licensees' normal method of operation. A Regulatory Policy Statement (C-119) on the use of human factors knowledge in the life cycle of Canadian nuclear facilities[22] is under review internally, and will be published for comment later this year. The Policy proposes that licensees must submit evidence to the AECB of the methods that they have adopted to incorporate a knowledge of human factors into all the phases of a nuclear facility life cycle. The Policy proposes that a Human Factors Program Plan should be submitted by a licensee to support the application for approval to construct a new facility, or make major modifications to an operating facility. It also proposes that the Plan define how human factors knowledge is to be used in design, construction and operation and the methods used to apply such knowledge. The Policy also proposes that a report should be submitted to the AECB when an initial operating licence is sought, or at relicensing, stating how the Plan is being implemented. We look forward to detailed discussions with designers and operators on this most important safety topic. We also envisage that this general policy will be followed by a number of detailed guides. We are also looking at guides and standards produced by other industries to see how the experience of others can help us.

9. SOFTWARE RELIABILITY

CANDU Nuclear Power Plants have always used computerized systems for reactor regulation and fuelling machine control; reactor designers and operators have felt comfortable about their ability to design and use these systems. In the past, computerized
regulating systems have not received much regulatory attention as they are backed up by the special safety systems which used analog, hard-wired components. It has always been assumed that the special safety systems would be capable of handling any failures of computerized systems originating in either the software or the system hardware -- although there have been doubts about this assumption.

Ontario Hydro's decision to use computers to control SDS1 and SDS2 led us to consider how best to satisfy ourselves that the systems would be highly reliable, and would not do something that was not intended. (An example of the latter was the fuelling machine failure at Bruce "A" in January 1990, where a software error caused an untimely release of the refuelling bridge.)

Our review of the Darlington software required enormous effort on both our part, and on Ontario Hydro's part, to the point where the expected gains in using the technology were rapidly being lost. Why did this occur? What we attempted to do, put simply, was to review the specification for the software and then examine the coding to assure ourselves that the code would do only what was expected of it. We found that the specifications were ambiguous and incomplete, and the codes were written with no real limit on the extent to which one part of the code interacted with another part. We concluded that the codes as written would be unmaintainable (in the software sense), since neither ourselves nor Ontario Hydro could afford the effort to review changes. On the other hand, if the code was rewritten, starting with clear, unambiguous and complete specifications, if the degree of "crosstalk" in the code was strictly controlled, and if the code was tested by challenging it as it would be challenged in operation (i.e., "trajectory testing" of the code installed on the hardware to be used), it would be much easier to review, maintain and satisfy all parties that it does only what is intended. The promise represented by computerized systems could then be fulfilled.

The use of computers in nuclear power plants is inevitably increasing. New or replacement controllers, monitor and display systems, data acquisition and interpretation systems, and "smart" instruments will unavoidably be software or firmware controlled.

We concluded that it was essential that standards be prepared that specify precisely what can be expected of software that must meet a very high level of reliability.

A standard is being developed which builds on the lessons from Darlington. The AECB has published some of the ideas it believes should be incorporated in the standard. Ontario Hydro and AECL are developing, through OASES and CSA, a comprehensive approach to the design, documentation and verification of computerized systems. These standards will enable software to be used in many safety-critical applications because the proposed design, analysis and testing procedures will allow the systematic
comparison of the program behaviour with the engineering specifications that the computerized systems must fulfil. The standard will include a procedure for categorizing software so that they may be applied to the software used in applications which call for other levels of criticality. We will closely monitor the work of these groups to ensure that their output meets our safety requirements. At this point in time we anticipate that the industry-produced standards will meet our needs and it will not be necessary for us to write our own.

10. ALARA (C-129)

The General Amendments to the Regulations require that licensees demonstrate that doses received by workers and members of the public as a result of their operations are as low as reasonably achievable. Although this principle has been in operation for many years in Canadian nuclear facilities, and is a well established principle internationally, it has been difficult to discern precisely how the ALARA principle has been applied in a systematic way by many of our licensees. The new requirements in the General Amendments imply that the steps that have been taken, or are being taken by licensees should be both systematic and auditable. A licensing guide on the application of the ALARA principle has been in preparation for a number of years. In preparing the Consultative Document, we have found it difficult to define an approach which is practical, easy to use, and understandable to all licensees in all parts of the industry. Complex cost/benefit analysis methods, as have been proposed by the ICRP, for example, are unlikely to be suitable for general use, and we do not propose to require them. We are more interested in ensuring that, whatever process is chosen by a licensee, it is systematic and that it follows a structured process so that all the important aspects are included, and that it is auditable - that is, an independent assessment of the process can be made. The licensing Guide on the ALARA principle proposes a simple algorithm (Fig. 1) which identifies a lower level of dose, which, if met, would be considered to be optimized - viz. around 50 μSv per year individual dose to the public, 1 mSv per year individual dose to workers, and a collective dose of <1 person Sv per year.

We expect Document C-129 to be published for consultation in early fall of '92.
Figure 1
General Decision Making Process for Meeting ALARA Guidelines.
11. POLICY STATEMENT ON BACKFITTING

Several groups, including the Ontario Nuclear Safety Review\textsuperscript{19} and the Advisory Committee on Nuclear Safety\textsuperscript{20}, have recommended that the Board publish a policy statement on backfitting of "upgrades" to existing facilities. Such a policy statement should include consistent criteria for assessing the need for backfitting to keep the risk of continued operation within acceptable limits and for assessing possible negative impacts, such as increased work-force exposures.

Our approach to backfitting to date is to ensure that the risks associated with continued operation are maintained at the levels no greater than those perceived to have been present when the plant was first licensed for operation. However, decisions on allowing continued operation during the period required to implement backfitting, where it has been judged necessary, and the time allowed to complete this work have been made on a case-by-case basis. These decisions have taken account of factors such as the extent of the changes, their relative importance to safety, and the worker dose expected to result from their implementation.

Ideally, we would like to develop a policy that would deal with the issues of the need for backfitting, the acceptability of continued operation, and the allowable schedule for implementation in a consistent manner. Our current efforts are aimed at defining:

1) The minimum requirements for the protection of health, safety, security and the environment that every licensed facility will have to meet, regardless of the impact on their operation.

2) A consistent and auditable process that the Board can rely on to arrive at a decision whether further improvements are reasonably practicable and should be required. This process would consider both the positive and negative effects of a proposed change.

3) The role to be played by value impact assessment.

These issues are, of course, very complex and involve social and political as well as technical judgements. Thus, we expect the development of this policy to be a protracted and difficult process. It will be made more complex following the publication by the IAEA of Issue Paper III at the conference on the Safety of Nuclear Power\textsuperscript{36}. The conference concluded that plants built to earlier standards need to be justified against current safety thinking. If adopted in Canada, this may have implications on our backfitting policy, but they are not expected to be onerous.
12. THE AECB’S LICENSING PROCESS FOR POWER REACTORS

The AECB’s licensing process for power reactors was described in report AECB-1139, published 1979. This report is now out-of-date. For example, it does not discuss the need for payment of licence fees, as required by the Cost Recovery Regulations, or the need for environmental assessments, as required by the Environmental Assessment and Review Process Guidelines Order. We are now preparing an updated version. This version will also discuss the effects on the licensing process of the proposed general amendments to the Atomic Energy Control Regulations.

This document will define the process to be followed to obtain a Site Preparation Licence, a Construction Licence and an Operating Licence for a nuclear power station. However, it will not define the safety and licensing requirements that must be met at each stage. These requirements will be codified in separate documents. We have already started work on codifying requirements for approval of a Site Preparation Licence. Defining the requirements for the early stages of the licensing process will allow prospective applicants to plan their own activities so as to minimize the risks of delays in licensing.

CONCLUSIONS

Since Treasury Board approved an increase in the number of staff at the AECB, we have started a program of documentation of requirements. Our basic licensing principle of stating what the overall objectives are without mandating how a licensee chooses to meet those objectives will be maintained; the licensee must remain responsible for the safety of the facility. This paper has highlighted a number of initiatives that are currently in progress. A number of others are also being prepared: C-118 on Derived Emission Limits; C-123 on Releases from Licensed Activities other than Nuclear Facilities; C-130 on Monitoring Requirements for Uranium Mining and Processing Facilities, etc. All will follow the Board's Consultative Document Procedure to ensure all those who are interested have had a chance to comment on them. For some of the more controversial or technically difficult initiatives, we will be seeking input before they are published as a formal Consultative Document. I am sure we can rely on the cooperation and frankness of view which has characterized the Canadian nuclear industry in the past to ensure these documents are of real value to the public, designers, operators, and regulators alike.

REFERENCES:


(13) AECB, A. Faya, "Notes of C-6 Workshop held on 29 October, 1990 at AECB".


SESSION 10

RENOVATION OF EXISTING STATIONS

SESSION CHAIRMAN

R. A. Brown
Ontario Hydro
INTRODUCTION

The topic I'll be discussing is the front end work associated with the Bruce A Rehabilitation Program. The Bruce Nuclear Generating Station is located on Lake Huron as part of the Bruce Nuclear Power Development. It is one of 5 multi-unit pressurized heavy water reactor stations forming the Nuclear Operations Branch of Ontario Hydro.

The four Bruce A units are rated at 795 MWe and were brought into service between 1977 and 1979. Current running hours average 85,000 hrs.

Recently the operating performance of Bruce A has fallen short of target levels ... target being 85% capacity factor.

Contributing to this decline was the amount of outage time necessary to perform inspections and maintenance on reactor pressure tubes, which were approaching planned service life and associated change-out under the retubing program. But there were a number of other contributors which would prevent satisfactory operation and would not be corrected by retubing alone, so the decision was made to scope out and commit a rehabilitation program on the balance of plant.

Hence, the objective of the overall exercise is the attainment of target 85% capacity factor for balance of plant life (to year 2018) by the implementation of Retube and Rehab.

It was also recognized early on that these technically based programs would restore performance, but a revised approach to operation and maintenance would be required to maintain satisfactory capacity factor levels through end of life.

The rehabilitation work is therefore one part of a 3-pronged approach to long term performance improvement, the other 2 areas consisting of:

Procedural - adoption of a pro-active reliability centred maintenance program
- optimization of maintenance effort through the involvement of maintenance staff in the Branch Quality Improvement Program (QIP)

Resource - adequate levels of skilled staff to implement the operations/maintenance/surveillance programs.
It is crucial, however, that the plant be physically capable of supporting 85% capacity factor operation, hence the front-end importance of the rehabilitative program.

The justification process started in earnest with the release of $7M in May 1990 to fund the scoping, preliminary engineering, estimating and preparation activities for a rehab program expected to cost between $400M and $800M for all 4 units. The objective was to commit an overall Rehab Plan in June '91. It should be noted this was to be incremental to the $1.06B approved for the retubing of Units 1 and 2.

The first step was to define the program scope. It was known from experience at Pickering that the overall Rehab program would have 3 main components:
- maintenance
- inspections
- projects

The maintenance and inspection programs were coarsely defined (in terms of funding requirements) based on previous experience; so while some scoping and detailed definition work went on in these programs during this time frame, the greatest effort was devoted to nailing down the project portion of the program.

As a starting point, Technical Section staff at Bruce A had been compiling a total Rehab project list in anticipation of the commitment of the Rehab program. It was commonly referred to as the "wish list". Using this as a starting point, the scope was fine tuned using a number of inputs:
- Technical and Operating Staff input
- Maintenance trends
- Inspection Results
- Third party reviews (more later)
- Incapability analysis (past and projected)
- System Planning analysis

We'll now spend some time looking at details of particular facets of the justification process.

**PROJECT MANAGEMENT APPROACH**

Ontario Hydro's recent experience with rehabilitation programs had not been very positive. Therefore a key step was setting up an appropriate project management approach that would facilitate cost/scope/schedule control and still effectively meet customer needs.

From this need evolved the 3 party team approach. From early on in the scoping process Engineering, Construction and Operations collaborated together at both program and project level, with the heart of the approach based on individual project teams. These
teams became intimately involved in up-front problem definition, justification for release, and post release implementation with project accountability for cost, schedule and deliverables. Additional support teams were put together to deal with overall program concerns (Rehab Program Management Team, Planning and Control Team, Licensing Team, etc.).

This team approach represented quite a shift from past practice and there have been and continue to be things arising as part of the learning curve experience. Overall however, the approach is reviewed as very positive by the participants, and while it's still early days in the 8 year program, we are seeing definite benefits due to 3 party input to problem solving and project ownership.

As part of our managed approach, each project was scheduled for installation in particular outages defined in the 10 year outage plan, which allowed us to establish schedules, resource histograms and cash flows for each project. This slide contains quite a bit of detail, and is available in the handout package, but it does show each project (left column) and it's installation date (right hand columns). This then allowed summing of project components to give overall program resource and cost requirements, which we now use as a baseline to monitor against.

**INCAPABILITY ANALYSIS**

Referring again to the incapability "pie graph", it was fairly easy to line up areas where we had historically experienced incapability and projects to resolve problems. What was more difficult was making convincing arguments about things which has not caused many problems to date but showed unfavourable precursors as well as the overall argument regarding projected capacity factors if all that was done was retubing.

If we were magically able to remove the wedge from the pie graph dealing with pressure tube related incapability, lurking underneath were other problems which would have contributed anyway.

The way we dealt with this challenge was an analytical incapability factor project exercise.

Based on a combination of historical date and subject matter expert input, algorithms were generated which showed expected incapability for selected projects (one shown here for Feedwater Heaters), and when summed, the overall incapability projections under 2 scenarios implementation (the lower line) and "do nothing", the higher the line.

We also got independent verification of the methodology so as to establish the credibility of the process.
Analysis confirmed that not implementing the balance of plant rehab program would prevent us meeting capacity factor targets, by a significant amount as can be seen. This type of analysis had not been attempted before from what we could gather during an information search. Further details of the method can be obtained from Ontario Hydro's Nuclear Operating Standards Department, which developed the approach.

**STATION VIABILITY ANALYSIS**

Due to the amount of money under discussion to fund the Rehab work, the System Planning Department within Ontario Hydro costed out the most likely replacement energy scenario to give a cost/benefit comparison.

It confirmed that taken to Net Present Value for meaningful comparison, the costs associated with Rehab, Retube and ongoing operational requirements represented a sound business decision, with about a 2 1/2:1 payback compared with the "replace" option.

**THIRD PARTY REVIEWS**

In putting together the program and in preparations for approval, a wide ranging consultative process was used, tapping into various parts of the organization who had a stake in or could be affected by this program. Input was sought from Comptrollership, Environmental Division, Human Resources, Corporate Relations, Power System Operating Division, Nuclear Integrity Review Committee, Nuclear Safety Department, to name a few. Additionally, we had been holding regular communication sessions with site AECB staff to keep them the picture.

Of particular note are the use of AECL to review Bruce A design and operation, and the "Rehab Review Panel".

The AECL study was commissioned to run in parallel with the early scoping work, and intended to focus on operational complexity and ways to minimize it. In the end recommendations were made which would address existing or developing plant technical deficiencies; it was gratifying to note that all of the technical recommendations made were being addressed in the evolving program scope.

The Rehab Review Panel was intended to periodically review and comment on our approaches, assumptions and program details as we moved towards approval.

The panel consisted of senior staff from AECL and Ontario Hydro, who brought many years of experience to bear on the program; the
input proved invaluable as both a fine tuning medium and validation tool for our direction.

A series of 3 review meetings were held, the final one being at our start up the approval line on March 27/91.

APPROVAL

On June 10/91, our original target date, our request for approval for an $854M four unit rehabilitation program was approved by the Ontario Hydro Board of Directors.

This was noteworthy not only because it was our originally targeted date, but received approval from a Board which had a new chair and 3 newly appointed members at that (their first) meeting.

SUMMARY

This presentation has briefly focused on the approaches taken in assembling and getting the overall Rehab Program Plan Commitment approved. We have assembled and are now executing a component based Rehab program, and incorporating necessary elements of planning and project control at the front end.

Recent work (since approval) has concentrated on project release and engineering leading to implementation (still using the team approach), detailing the life assessment inspection program and defining the restorative maintenance program.

While we seem to be off to a good start, we have quite a bit of work ahead of us in the years to come.

"To whom much is given, much is expected".

Thank you.
INTRODUCTION

On November 30, 1990 with the reactor operating at 100% full power, a routine recycle fuelling operation was attempted on channel N12 of Unit 2. However, the fuel carrier containing two irradiated bundles, stalled short of its home position while being advanced into the outlet end fitting. The fuel carrier was positioned with difficulty but fuel could not be pushed into the channel. The fuelling operation was aborted however, problems were encountered during attempted reinstallation of the shield plug and closure plug. Indications were that there was debris in the outlet end fitting and both the Gaseous Fission Product monitor and heat transport system chemical analysis were indicating damaged fuel in the south loop, the loop containing channel N12. On December 23, 1990 the unit was shutdown to install a maintenance cap on the end fitting. The Unit restarted on January 8, 1991, but ran for only a few days.

Unit 2

Unit 2 fuel load started on June 17, 1989 and First Criticality was achieved on November 4, 1989. Due to problems unrelated to fuel, Full Power was not achieved until July 1, 1990. Unit 2 was operated at high power levels for most of the period from July to November, 1990 until the incident occurred.

On January 12, 1991 the fuel carrier containing the recycled fuel bundles was discharged to the Irradiated Fuel Bay, at which time fragments of fuel elements from the bundle in position 1 of channel N12 were discovered (Figure 1). Unit 2 was shut down and an investigation into the cause of the fuel damage was initiated.

The evidence from the fuel fragments (subsequently confirmed) was that part of the N12 position 1 bundle, consisting of some centre and inner ring elements broke free of the bundle and moved through the fuel latch prior to the refuelling attempt (Figure 2).

Subsequent to the shutdown of Unit 2, in-reactor inspections of the downstream end plates of selected bundles in position 1 were performed with CIGAR video camera inspection equipment, which identified a number of crack like indications.
Following the first CIGAR inspection, preparations were made to ship irradiated fuel to AECL's Chalk River Laboratories and Whiteshell Laboratories for examination in hot cells.

The hot cell examinations provided the best characterization of bundle damage, including detailed end plate crack characterization and also bearing pad and spacer pad fretting wear. Observations of visually indicated partial and incipient cracks in the hot cell examinations were influential in directing the early Irradiated Fuel Bay inspections and CIGAR video camera inspections.

Inspection of discharged fuel bundles in the Irradiated Fuel Bay (IFB) is a normal part of fuel performance monitoring. However, following the N12 fuel damage finding, a significantly expanded program of IFB fuel bundle inspections was initiated. The initial focus was to inspect discharged bundles from the first charge of Unit 2 that were available in storage modules in the fuel bay. The available bundles were those from positions 10, 11, 12 and 13 which had been discharged during normal four bundle shift fuelling.

By the end of April 1991, a number of channels with visible end plate cracking indications from CIGAR video camera inspection were defuelled. Inspection provided evidence of extensive fuel string wear and damage in channels D2K12, D2K13 and D2J13, ranging from multiple cracks in a number of bundle positions, through heavy spacer sleeve interaction wear on outboard bearing pads of bundles in position 13, to varying degrees of inter-element spacer pad and end plate impression wear along the fuel strings.

A data collection program to assist in identifying the cause of fuel damage was undertaken in July 1991.

Characterization of damaged fuel in Unit 2 has recently been completed. Endplate cracks have been identified on fuel from 8 channels (J12, J13, K12, K13, M13, N12, Q12 and R13). Severe bundle 13 bearing pad wear, due to interaction bearing pad with the spacer sleeve, has been observed on fuel from 7 channels (J13, J14, K07, K12, K13, M12, V20).

CIGAR pressure tube inspection has been performed on 19 channels. Fuel Channel K13 was replaced due to a 0.5 mm deep fret mark, as well as a desire to physically examine fuel channel components. Recently, the entire assembly was sent to CRL for characterization.

The CIGAR inspections did not identify any other pressure tube that has to be replaced, although channel N12 will be changed due to fuel debris in the end fitting liner.
Unit 1

Unit 1 fuel load started on August 1, 1990 and first criticality was achieved on October 29, 1990. Full Power operation was achieved January 12, 1991 and continued until March 9, 1991 when the unit was shutdown for a planned maintenance outage. AECB approval to restart the unit was not secured until August 10, 1991 due primarily to concerns over the fuel damage found in Unit 2. As part of the Unit 1 restart an extensive data collection program, similar to that undertaken on Unit 2, was undertaken. The unit operated from early September 1991 to October 17, 1991 when another planned maintenance outage started. An extensive fuel inspection program during this period of operation did not identify any significant fuel damage. AECB approval to restart the unit was obtained December 24, 1991 and the unit operated until January 26, 1992 when heat transport revised (and more restrictive) Iodine levels exceeded the shutdown limits. The Iodine excursion was later found to be due to debris fretting wear of fuel elements and was not associated with endplate cracking or excessive bearing pad wear. Subsequent to the shutdown, an endplate crack was identified during IFB inspection of a bundle from channel M13. As well, significant bearing wear was observed on fuel discharged from two channels (H13 and K18). It was concluded that the same mechanism which caused the damage on Unit 2 was present on Unit 1, and the decision was made not to restart the unit until a design solution was installed.

Organization

Following the identification of fuel fragments from channel N12, an investigation team was established. The objectives of the team were to determine the cause of the N12 failure, and also to determine the implications for continued operation of Unit 1 and Unit 2 return-to-service. Weekly Technical review meetings were held starting in late January 1991. In March 1991, a Vice Presidential level Steering Committee was established.

The structure and membership of the investigation team has evolved as the scope of activities has changed. The current organization is shown in Figure 3. At the present time, over two hundred staff from Ontario Hydro, AECL and other organizations are involved in the investigation.

The initial activities of the investigation team were concentrated on evaluating potential scenarios whereby the observed break-up of the N12 bundle in position 1 could have occurred, assessing the potential implications of bundle break-up occurring in-reactor, establishing a fuel inspection plan and reviewing operating history. The work was focused in large measure on identifying the causes of fuel damage observed in Unit 2 as shown in Figure 4.
The first scenarios addressed involved possible fuel manufacturing defects, excessive force during manual loading of the first charge fuel, debris fretting damage to the end plate, and possible mechanical overload of the bundle by overextension of the fuelling machine ram during the N12 fuelling operation. With very limited information available, the most logical scenarios were ones involving mechanical overload induced ductile failure mechanisms which could damage the position 1 bundle.

In parallel, tests were initiated in the flow visualization rig at the AECL Sheridan Park Engineering Laboratory (SPEL) to investigate the vibration behaviour of loose elements in a downstream bundle and possible vibration induced fretting of the pressure tube. There was a suspicion that low cycle/high amplitude fatigue was the mechanism that had caused the break-up of the D2N12/1 bundle, based on preliminary results of detailed examination of an endplate fragment from D2-N12/1 at Chalk River Laboratories. A series of tests were performed in the SPEL flow visualization rig with pumps cycle on and off. However, these tests did not produce any end plate cracks, which was indicated that low cycle/high amplitude fatigue was a doubtful mechanism to cause the observe damage.

On Unit 1 in March 1991, a series of vibroacoustic endfitting vibration and pressure pulsation measurements were taken and these measurements indicated pulsations and vibrations at the 150 Hz vane-passing frequency of the pumps, as well as components at 30 Hz and in the 6-12 Hz range. Since the pressure measurements were taken at the end of long instrument lines, the 6-12 Hz components were most probably associated with instrument line resonances excited by broad-band turbulent eddies in the flow. Conflicting views existed regarding the significance of the higher frequency pressure pulsations and vibrations, resulting in a wide range of varying hypothesis being formulated in the ensuing months. As part of the effort to resolve issues pertaining to possible fuel damage mechanisms, testing on Unit 2 was performed in July 1991, and on unit 1 during the August, 1991 restart. Hydraulic, fuel bundle and fuel string modelling and analysis were also initiated in this time period.

During the period from April to early June 1991, a wide range of analysis and testing activities were focused around possible low cycle fatigue mechanisms: large amplitude flow variations due to pump starting and stopping, flow variations due to boiling at channel exits, static bundle overload due to excessive hydraulic drag load, flashing and waterhammer pressure surges in the ROH balance lines and pressure surges associated with pump startup. These areas were pursued, in part, because of observations from the operating history of Unit 2 and, in part, from the postulation that cracks could have been initiated by some event, or series of events which had stressed end plates severely,
leaving the endplates susceptible to crack growth and propagation due to lower amplitude cyclic loads.

Metallurgical Investigation

In the first half of 1991, the metallurgical investigation included a number of review and testing programs related to establishing fuel bundle and materials properties. The properties of the welds between the fuel element end caps and the end plate were reviewed and tensile strength of the welds were tested for GE (Canada) and Zircatec fuel (both GEC and Zircatec provide fuel for Darlington. The specifications used are identical but there are slight differences in manufacturing technique). A series of small specimen and bundle fatigue tests were initiated to establish fatigue failure criteria under different loading conditions and temperatures. In addition, corrosion fatigue and possible contribution of delayed hydride cracking was investigated. The early fatigue life testing generated data regarding low cycle fatigue, driven mainly by the need to quantitatively assess the postulated low cycle fatigue failure mechanisms. Subsequently, the emphasis turned to high cycle low amplitude fatigue, as information was acquired from the Chalk River Laboratories hot cell examinations of end plate cracks.

In the summer of 1991, information was being generated from the metallurgy investigation regarding the interpretation of deuterium pickup and oxide thickness measurements from fuel bundle end plates, interelement spacers and bearing pads. These measurements were being used to infer information whether wear was ongoing or had started and stopped; whether wear had occurred under hot or cold heat transport conditions; and to estimate the time at which end plates had cracked. Attempts to use deuterium pickup measurements as indicators of wear at hot or cold conditions proved fruitless, and by November 1991, a consensus was reached that the measurements could not be used to draw any conclusions in this regard. However, work on interpreting oxide thickness measurements for inferring some wear characteristics and for crack dating has been ongoing since July 1991. Additional studies and reviews were undertaken to assist in quantifying wear rates on spacer and bearing pads and to identify areas of uncertainty in interpretation of observed wear characteristics. This information was of importance in terms of identifying possible conditions under which accelerated wear may have occurred and to differentiate ongoing wear from transient wear.

Metallurgical examination of endplate cracks established that the cracks are due to the result of low amplitude, high cycle fatigue with alternating stress levels just above the fatigue limit.
Loop Testing

By June 1991, with high cycle fatigue failure being confirmed as the primary mechanism for end plate cracking, and the extent of string damage in some Unit 2 channels, such as K12, Q12, K13, J12 and J13, evident from IFB inspection, the need for out-reactor loop testing of 13 bundle fuel strings became apparent. The early testing in the flow visualization rig at SPEL was geared primarily to the effects of hydraulic drag loads on the position 1 fuel bundle under steady flow conditions and large amplitude cycling over a range of flow rates. The results did not indicate any of the failure modes seen in-reactor. Loop testing was initiated at Stern Laboratories and SPEL to address vibration and wear behaviour under a range of hydraulic conditions. The direction of the loop testing program was significantly influenced by the Unit 2 testing program performed in July, 1991 noted earlier. In October 1991, loop testing was also initiated at General Electric (Canada) in their Darlington fuelling machine test facility.

The Unit 2 measurements of pressure pulsation and end-fitting vibrations at 150 Hz, as well as flow variation measurements from the Reactor Regulating System (RRS), Fully Instrumented Channels (FINCH) and the Shutdown System (SDS), 1 and 2 safety instrumented channels were employed to direct some parts of the loop testing program. The objective was to establish the behaviour and sensitivity of fuel response to flow and pressure variations similar to those observed in reactor. By quantifying fuel response to the range of hydraulic conditions, a more definitive identification of dominant mechanisms was sought.

Another series of tests, performed on the Bruce channel in the Nuclear Process Components Test Facility at Ontario Hydro's Research Division, was geared to investigating the response of fuel strings to external mechanical vibration of the end-fittings. This program involved both radial end fitting vibration and axial vibration of the fuel string.

Additionally, a number of tests have been performed in the different loop facilities to support analysis and interpretation of test data from Units 1 and 2, as well as to assist in establishing suitable monitoring criteria for Unit 1. These tests include characterization of the frequency response of instrument lines and determination of fuelling machine transfer functions (gain and phase at fixed frequencies as a function of coolant temperature) to assist in interpreting pressure measurements obtained from transducers installed in fuelling machine heads.

Some of the loop tests at Stern Laboratories and SPEL were geared to supporting analytical modelling of hydraulic acoustic phenomena in the heat transport system. This work has included
tests to determine sonic velocities in fuel channels and feeders, and tests to identify and measure fluid dynamic acoustic behaviour in feeders and fuel channels. In addition, tests were conducted to measure such parameters as fuel bundle and fuel string stiffness, which were of importance to modelling of fuel string behaviour.

**Acoustic Modelling**

The acoustic pressure pulsations observed in unit test data initiated hydraulic modelling and analysis activities aimed at determining whether the pressure pulsations originating at the HT pumps are a significant contributor to the fuel damage. In addition, design modifications to reduce or eliminate the acoustic resonance behaviour were under consideration from the early stages of the investigation, and acoustic analysis was required to assess proposed options.

Initially two computer codes, ABAQUS and a proprietary code of Engineering Dynamics Incorporated (EDI), of San Antonio, Texas, a consultant retained by Ontario Hydro, were used to perform this analysis.

Later in 1991 a computer code, WHAM, recently developed by Ontario Hydro for assessment of waterhammer related consequences of pressure tube failure, was modified and also applied to this analysis. This code has the capability to handle both mass transport related hydraulic flow behaviour, as well as acoustically propagating hydraulic behaviour.

Experimental studies in support of the acoustic analysis work are being conducted at OHRD Nuclear Process Components Test Facility (NPCTF) and the University of Toronto Institute for Aerospace Studies (UTIAS). At the NPCTF, the Darlington HT Pump Test Loop is used to characterize the Darlington HT Pump. Attached to the same loop, a small scale model Darlington HT RIH/feeder arrangement is used to evaluate proposed design solutions. At the UTIAS, a similar model using air rather than water as the fluid medium is being developed for the same purpose.

**Fuel Bundle and Fuel String Modelling**

The IFB inspection program which involved regular examination of Unit 1 bundles discharged from positions 1, 2, 12 and 13, using a modified four bundles push scheme, was not indicating any significant wear or damage similar to that observed in Unit 2. These observations raised questions regarding the source of differences between the two units. In attempting to generate answers, additional analytical work was initiated related to fuel bundle and string modelling and factors that may affect fuel bundle and string response experiencing variations of hydraulic loading.
The objectives of this analytical modelling work are to develop structural models of a fuel bundle and the fuel string, and to determine the important parameters that govern the in-reactor fuel response. It is of particular interest to determine whether mechanical resonances of the fuel bundle or fuel string are involved as contributing conditions to fuel damage in Units 1 and 2. The results of the analysis will be used to compare the predicted fuel damage patterns to the observed in-reactor damage patterns. The analysis will also be helpful in determining the timing of the failures in conjunction with the results of the oxide thickness program.

In addition, a number of experimental activities were initiated to generate data to quantify key parameters in the analysis models. This experimental work includes tests to establish the vibration behaviour of bundles, stiffness components of unirradiated fuel bundles, stiffness of UO₂ pellets, and vibration characteristics of a string of thirteen bundles.

**Damage Hypothesis**

In the course of the investigation a large number of potential fuel damage mechanisms have been postulated and evaluated. It should be noted that in the early stages of the investigation when there were few available facts, the postulated mechanisms covered a very wide range of possibilities. Subsequently, a number of these have been firmly established as being not relevant.

Although some uncertainties still exist, the damage mechanism believed to have caused the damage observed in Darlington is pressure pulsations in the PHT system at 150 Hz.

This mechanism involves amplification of pressure pulses originating from the primary heat transport pumps as the impeller vanes pass the pump cutwaters. The pulses, which occur at the 150 Hz vane passing frequency, are amplified by acoustic resonance, in the pump discharge piping, reactor inlet header or inlet feeders.

In addition, varying degrees of either attenuation or amplification of the pressure pulses will occur in individual channels. The response in individual channels is determined by such factors as inlet and outlet feeder lengths and coolant temperature (which determines the local sonic velocity). The closer a particular channel is to a resonance at 150 Hz, the more likely it is to exhibit amplification of pressure waves. The net effect is that combined travelling wave/standing wave pressure pulsations occur in fuel channels, with magnitudes governed by location of feeder connections on inlet headers and the feeder/channel response characteristics.
The fuel string response to pressure pulsing can depend on the axial alignment of any standing wave with the fuel string itself and with the proximity to 150 Hz of a natural frequency of the fuel string.

Unirradiated fuel strings tested at cold conditions, indicate that the response falls off above 140 Hz, suggesting a fuel string resonance at or below 140 Hz. This is consistent with fuel string modelling which predicts a fifth mode natural frequency at 130 Hz. The natural frequency increases with temperature and power and is affected by time at temperature and by irradiation, so that the tuning of the fuel string to 150 Hz is possible at some point in time.

In addition to fuel element stiffness effects, creep of the endplates under the combined effects of hydraulic drag loading and irradiation can influence the fuel string through load shedding. This factor could be involved in causing high end plate stresses in channel outlet bundles, which would result in a progressive extent of damage up the channel as seen in some Unit 2 channels. It would also be expected to occur more readily in Unit 2 due to the fuel loading pattern differences between the units, which resulted in more GE (Canada) fuel in the central region of the core in Unit 2. Unit 1, on the other hand, had predominantly Zircatec fuel in the centre of the core, which is likely to load shed to a lesser extent because the end plates were more concave.

Potential Solutions

In parallel with the investigation into the causes of fuel damage in Unit 2, a number of activities were initiated to assess and design potential solutions that would mitigate the effects of the 150 Hz pressure pulses from the pump. These activities were premised on the basis that the 150 Hz pulsations were the primary cause of the fuel damage. The possible solutions considered were:

1. Replace the existing 5 vane pump impeller with a 6 or 7 vane impeller to change the vane passing frequency of the pressure pulses from 150 Hz to 180 Hz or 210 Hz, respectively.

2. Add an acoustic filter with a volume-choke-volume arrangement to the piping between the HT pump and the RIH to reduce the amplitude of the 150 Hz pressure pulses entering the header. This device acts as a low pass filter that attenuates incoming pressure pulsations above a threshold value.

3. Introduce active cancellation of the out-of-phase pulses that are produced at each pump cutwater such that the
amplitude will be attenuated before reaching the header. In an ideal situation, perfect cancellation would result in absolutely no pressure pulses downstream of the cancellation point.

4. A number of smaller scale piping modifications based on principles of acoustic filtering, detuning the 150 Hz frequency from the pump or partial active cancellation were considered.

5. Detune the mechanical resonance occurring at 150 Hz within the pump discharge lines and the RIH. The header vibration is predicted to amplify the pressure pulses in the header.

6. Add a fuel supporting shield plug (FSSP) to the outlet end to support the central region of the outlet bundles, minimize fuel string axial motion and thus minimize the alternating stress component. This option would be primarily a solution to end plate cracking since outreactor tests have shown that it is not effective in eliminating axial motion of the inlet bundle.

7. Reduce the flow rate in fuel channels, by trimming the impeller or adding a flow restrictor, to the design level or a lower value. The intent of this modification is to reduce the main stress level in the endplates and thereby, alleviate the endplate cracking problem. Based on Unit 1 inspection results, this option is not effective in eliminating inlet bundle wear.

8. Modify the inlet shield plug to produce a more streamlined flow into the channel and minimize the bundle rocking as a potential contributor to inlet bundle wear.

CONCLUSION

An intensive, wide-ranging investigation into the causes of the Darlington fuel damage has been underway since the occurrence of the N12 event on Unit 2 (Figure 5). Although this investigation has not yet concluded, a number of definitive statements regarding the fuel damage can be made.

Endplate cracking is due to high cycle fatigue occurring at amplitudes just above the fatigue limit. The cracking of Unit 2 fuel bundles appears to have occurred at distinct periods in time and the cracks have developed over a relatively short time periods.

Endplate fretting wear occurs down the fuel string with a high incidence of impression wear occurring at the downstream bundles and at bundle position 9 on Unit 2, while Unit 1 indicates a high incidence at bundle positions 8, 9 and 10. The incidence of wear
at bundle positions 12 and 13 is low on both units. This, together with hot cell examination of some wear marks, indicates a predominant relative axial movement along the fuel string. This is also consistent with spacer pad wear, particularly between rings of elements. In addition, the pressure tube fretting wear on channel D2K12 is consistent with the higher impression wear of endplates in the region of the position 8, 9 and 10 bundles.

The spacer sleeve interaction wear of outboard bearing pads shows evidence of axial wear movement, as inferred from fret marks on the bearing pads and the dimensions of the pressure tube fret marks. However, the possibility of channel inlet flow contributing to bundle 13 bearing pad wear remains open. Certainly, the Bruce experience would suggest that some Type 3 wear could be expected, but at a significant lesser frequency than being observed at Darlington. No definitive conclusion has been reached regarding the mechanism, or mechanisms causing bearing pad wear.

The clearly established 150 Hz resonances in the reactor inlet headers and inlet feeders at hot conditions, together with the indications of a significant number of Unit 2 channels with damage exhibiting good acoustic transmission response, has contributed to this being considered the dominant mechanism causing fuel failure. Practical design solutions have been developed to significantly reduce the amplitude of the pressure pulsations and reduce the heat transport system sensitivity to resonant conditions. These are expected to significantly reduce the potential for incurring further fuel damage. In part, demonstration of the effectiveness of some of these modifications will come from Unit 3 testing.

Acknowledgement: The authors would like to thank J.C. Luxat who coordinated the preparation of the "Report on the Investigation to Fuel Damage Causes Following the Unit 2 N12 Event" from which the majority of this paper was taken.
FIGURE 1
FIGURE 3

Darlington N12 Fuel Damage Investigation Team

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Chairman

E.G. Price
Metallurgy & Fuel & PT Data Interpretation

J. Skears
Design Solutions & Monitoring

Fuel Program

R.E. Pauls
Acoustic Resonance Modelling

J.C. Luxat
Flow Variation Assess't

Q.B. Chou
Modelling Co-ord'n

G.J. Field
Loop Testing

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R.R. Hosbons
AECL Metallurgy Coordination

A.D. Telfer
Design Solutions

P.T. Truant
Fuel Inspection

J.H.K. Lau
Fuel Modelling & Analysis

D.R. Meraw
Unit 2 Return to Service
FIGURE 4

OVERVIEW OF INVESTIGATION ACTIVITIES

- FUEL INSPECTION & EXAMINATION
- METALLURGY
- UNIT DATA
  - Operating
  - Chemistry
  - Testing & Monitoring

- FUEL DAMAGE
- HT SYSTEM BEHAVIOUR

- FUEL DAMAGE HYPOTHESES

- FUEL STRING MODELLING
- HT SYSTEM ACOUSTIC MODELLING

OUT-REACTOR EXPERIMENTAL PROGRAMS
FUEL INVESTIGATION MILESTONES

Figure 5

100% POWER

UNIT 2

UNIT 2 SHUTDOWN

PLANNED S/U

100% POWER

UNIT 1

UNIT 1 SHUTDOWN

UNIT 1 SHUTDOWN

UNIT 1 SHUTDOWN

PLANNED S/U

POWER PRODUCTION

EVENTS

INVESTIGATION PROGRESS

REACTOR TESTS

U2 FM STUCK ON N12
U2 N12 FUEL FRAGMENT
U2 K12/O12 FOUND CRACKED
U2 CYCLE FATIGUE
CONFIRMED AT CHALK RIVER
U1/K12 FOUND WITH 100% WEAR OF BEARING PAD (113)
(STERIL XRF INTERPRETATION REQUIRED) 24 HOURS AT 150 HZ
U3 IMPELLERS CHOSEN AS SOLUTION TO BEARING PAD WEAR PROBLEM ON U1
U1 TEST WITH TRIMMED IMPELLERS CONFIRMS SIMILAR BEARING PADS TO HIGH CRACKING FUELS
U2 150 Hz ACOUSTIC RESONANCE FOUND AT ZERO POWER HOT
U1 7 VANE IMPELLER TEST RUN INDICATES WEAKNESS
U1,2 PUMP TEST RUN
U3 TEST CONFIRMS 150 Hz SOURCE OF PROBLEMS

FUEL DAMAGE THEORY—150 Hz
- HEADER ACOUSTIC AMPLIFICATION
- FEEDER ACOUSTIC AMPLIFICATION
- FUEL NATURAL FREQUENCY (≈ 150 Hz) TUNES IN WITH IRRADIATION

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1.0 INTRODUCTION

Keeping young at heart has as much to do with our attitudes as it does with the effort we put into maintaining our physical condition. Generally our quality of life and usefulness in society is enhanced as we grow older if we keep this life view. Several delegations have visited Point Lepreau in an attempt to determine what it is which allows this station to operate consistently so well. From a maintenance perspective the answer lies in two areas, the attitude of our staff and attention paid to maintaining the equipment. As a station we need to understand the answers to this question and as we enter the second decade of operation take steps to hold on to what has worked so well for us and maintain the attitudes and initiatives which will allow us to stay "young at heart".

The purpose of this paper is to discuss some of the issues which help make us successful and which require careful attention in the years to come if we are to continue to operate well as a station. It is recognized that many of the issues are more readily handled in a single unit station such as Point Lepreau. It is further acknowledged that to a very real extent the success has been made possible by close and cooperative relationships developed with other companies in the nuclear industry in Canada. In spite of the differences, it is hoped that these thoughts may be of some use to other operators who, no doubt, share with us the desire to keep stations running well as they age.

We are in the business of generating electricity safely and in a cost effective and reliable manner. This paper will focus primarily on maintenance/operational issues. Initiatives to help reduce the need to renovate or, in cases when renovation is unavoidable, to limit the associated down time will be discussed. The treatment of our maintenance program will not be comprehensive. The preventive maintenance program, for example, is excluded. The intent is to dwell on the team work issues and how they are manifested in shutdown maintenance periods. Point Lepreau experiences will be used to illustrate points. "Good practices" in areas such as outage preparation will be suggested.

The success of Point Lepreau is a result of a forgiving design being operated by a motivated work force the members of which have learned to plan well, work very well together as a team and
know when and where to get help. It is hoped that this paper will help those of us at Point Lepreau to commit to applying the necessary effort to maintaining the attitudes which will keep us "young at heart". In addition it may provide some food for thought for other operators faced with the similar problems of an aging station and a work force which may tend to become more complacent as the years pass.

2.0 FOUNDATIONS

Three underlying factors have made it possible to create a working environment which is conducive to the optimization of maintenance/renovation performance at Point Lepreau.

2.1 A Forgiving Design

Lepreau performance and that of our sister stations testifies to the successful operability of the CANDU 6 design. A number of engineering changes were instituted during the commissioning period at Lepreau to fine tune the design. To a lesser degree this optimization continues however the basic "package", with the obvious exception of pressure tube difficulties, has proven to be an excellent one.

2.2 Good Union-Management Relations

A good deal of effort is expended by both sides in maintaining an open and effective working relationship. The task is made somewhat simpler by all the site unionized staff being represented by one Local (2309) of the International Brotherhood of Electrical Workers. The local executive and shop stewards have been instrumental in establishing and actively supporting the "team work" attitude which will be discussed later and which, in my view, is the single most significant ingredient in the success of this station.

One indicator of the labour harmony enjoyed at Lepreau is the low number of grievances which are taken to the arbitration level. One grievance went to arbitration in 1991 and none in 1990.

2.3 Responsive Upper Management

The Lepreau station is the only nuclear unit in the New Brunswick grid and it represents about 25% of NB Power's generating capacity. It goes without saying that the successful operation of Lepreau is a major factor not only in the financial bottom line of the utility but the low power rates available to the industrial and domestic users in the province.
NB Power management has been responsive to the maintenance/rehab issues which have surfaced through the years by aggressively supporting the associated projects through the investigation and implementation stages. Lepreau staff have been provided with the time and travel opportunities to acquire the technical and contractor information necessary to make informed decisions on the best options to deal with problems. Budget resources have been made available to employ the correct "talent" and equipment to effect selected fixes.

3.0 ATTITUDE

This is the ingredient which makes the issues work that are to be discussed later in this paper. It is the component which is extremely difficult to orchestrate, but once established, must be deliberately nurtured.

There is no easy explanation as to how the positive attitude was established here. It is an oversimplification to speculate that it was good "chemistry" and good people growing into a positive spirit through some extremely difficult experiences during commissioning of the station. Whatever the cause, we are fortunate to have, in most cases, a motivated group of individuals at all levels who take real pride in Lepreau being a "world class performer" and who are dedicated to doing their individual best to maintain the performance. A few examples of this are provided.

- Recently a Delayed Neutron System tube was leaking excessively into one of the Reactor Vaults. The maintenance department was asked to crimp the leaking tube while reactor power was dropped to effect the repair. The job was to be completed in less than 15 minutes, in a radiation area while lying over hot tubes, to beat a poison outage. After a detailed preparation period the supervisor's biggest problem was not the job itself but dealing with the disappointment of the numerous volunteers who were not selected to make what turned out to be a successful repair.

- A welder refused to go home after spending many hours without an extended break making a difficult weld repair to a 30 inch pipe. A flaw in the pipe had forced the station to shut down. The welder knew that his work day was finished. In the event that NDE required a repair be done on his weld, he would not be permitted to make the repair due to the time he had already spent on the job. He agreed to leave only after the radiographs on his weld were developed and read.

- Superintendents in the maintenance and technical groups volunteered to provide radiation protection assistant duties for contractors during outages.
- When a problem develops in the station during "off hours" the individual contacted to respond insures that his supervisor and other interested individuals are appraised of the situation at home rather than being caught "cold" on their return to work.

The list could go on and examples are available in all work groups. In isolation, these types of activities may be common; however, we have come to expect this type of response regularly from our people. The point is that the work force care about the quality of their individual contribution to the performance of the station. The concern is how to maintain this spirit. The outlook is good as we are observing that the attitude is contagious. New people to the group readily join the team.

How we attempt to foster this attitude through attention to team work, communication and planning is discussed in later sections of the paper. Further initiatives which have proved to be helpful in addressing the attitude issues in the Mechanical Maintenance group are suggested here.

- Battle the urge to procrastinate when dealing with the people issues! At one point the number of issues aggravating individuals in the group got out of hand. A four person group (2 union, 2 supervisors) was established to identify the problems and deal with them. Some of the issues could not be resolved. However, the process of dealing with them and explaining the reasons why resolution was not possible was helpful. In spite of the many other demands of supervision in the field these people issues, often the least enjoyable and most difficult, must be handled with priority.

- Hire and promote people who will be team players and are apt to buy into the prevailing attitude in the group. Specific questions in interviews and careful reference checks are helpful. Once in the door, the new employee with a receptive attitude will catch the contagious spirit.

- As a supervisor, identify and personally deal with the individuals who are actively attempting to tear down the team attitude. Support the positive leaders in the peer group, isolate and via personal intervention deal with the negative leaders.

- Maintain a strong commitment to safety. If, for example, the safety glasses violations are ignored the philosophy will be undermined. As a result, more serious violations and resultant injuries will follow from a work group which is confused by the standard. This is the case for standards and expectations in other areas as well. Don't allow the motivated, positive
employees to become disillusioned by their observation of others not meeting standards and not being taken to task for it.

- Vary the job supervisory opportunities by periodically stepping up individuals to acting supervisory positions. In so doing, individuals are better prepared to fill these positions permanently and during shutdowns to direct more effectively groups of contractors. Our training program also enables variety in the types of skills used in the work place. The local Community College and others are used to prepare Industrial Mechanics, Machinists and Welders in the Mechanical Shop to be more effective in cross-trade situations. The Electrical and Instrumentation Shop also does this. Refer to Reference (1) for further details on this training program.

4.0 TEAMWORK

With supportive foundations the act of taking a motivated work force and focusing it on field maintenance and renovation activities will now be discussed. This will be dealt with in two broad aspects;

- project management: Point Lepreau strategies to structure and utilize resources to handle specific larger projects,
- outage management: methods used to prepare for and manage outages.

The Point Lepreau Maintenance Organization is described in Reference (2). Strategies adopted in the areas of teamwork and planning have worked very well for us. We have experienced success in completing maintenance and inspection tasks on schedule with a low frequency of rework. We receive very positive feedback from the contract personnel and supplier representatives who work with us in these areas. It is through continued effort and hopefully success in this that we will strive to maintain healthy equipment, minimize downtime and stay "young at heart".

4.1 Project Management

What follows is a description of the process which resulted in replacement of a Pressure Tube in record time (9 days) on the first attempt, location and repair of boiler tube leaks of less than 0.2 kg/h in less than 2 days following opening of the primary manway covers and replacement of all Horizontal and Vertical Flux Detectors in 7 and 21 days respectively. The Single Fuel Channel Replacement (SFCR) project will be used as an example. The process is a simple one. The trick is to pull it off by constructing a focused, well-prepared, well-supplied team.
4.1.1 The Team. The team simply consists of one overall coordinator and one representative from each work group which will be used in accomplishing the job in the field. In the case of SFCR, the coordinator came from the Fuel Handling Group and team members from Mechanical Maintenance (tooling, tool proving, training and manpower) Radiation Control (radiation protection and safety work plans) System Engineer (individual with system responsibility, work plans and procedures).

At various stages in the process the team is temporarily augmented with participants from Operations (permitry) Planning (outage logic net working) Licensing, Contractors (Canadian General Electric in this case) and whatever other resource persons are required.

4.1.2 The Process. Throughout the process the coordinator supervises the project. The representatives from the support groups may be supervised administratively by their own supervisors but they take all direction while working on the project from the coordinator. The coordinator administers the project budget and undertakes overall project responsibility through all phases. Regular team meetings are held to monitor progress and incorporate changes in direction.

a) PHASE 1 (Project Definition)

Identify clearly what it is you want to do and how to do it. In the case of SFCR this was relatively simple. However, in other projects (boiler sludge removal for example) it required the coordinator to visit stations with relevant experience, question vendors/contractors and with site management agree on a course of action.

b) PHASE 2 (Get help)

As a small utility it is imperative, especially in the case of larger projects, to import experience. The CANDU Owners Group (COG) has been a great help in this area through contacts and projects information available from the Working Parties and others. Long time associations with companies such as Babcock & Wilcox, Canadian General Electric (CGE), AECL and N.E.I. Parsons have been established and are used as required. In the case of SFCR, tooling was developed and built via a COG initiative and is jointly owned by N.B. Power and Hydro Quebec. Training support and experienced manpower to work with our staff in the field was obtained from CGE. The crew makeup was approximately 50% N.B. Power and 50% CGE.

The team members arrange for the contract services, tools and equipment in this phase of the project under direction of the coordinator. They arrange for the people and procure equipment necessary to support their own area of responsibility. When
possible the team members visit other stations to witness the activity they are preparing for as it takes place in the field.

c) PHASE 3 (Pre-Outage)

This is the time when the detailed preparation is undertaken in each team members area. The emphasis is placed on detail! The procedures are written, reviewed, approved, and then commissioned with the tooling on mock ups. The work plans are issued, incorporated in outage logic, and then interrogated to insure that the task is being executed in the most time-effective manner and that potential interferences with other outage activities are removed.

The support personnel are selected and trained. All consumable and support parts, equipment and services are obtained and checked to be available when required.

One significant initiative taken throughout this phase is a deliberate review of the tooling and procedures with a view to improvement. How can the task be refined to cut down on dose, time, or manpower, or be conducted more safely? Improvements were made to the SFCR and Flux Detector replacement tools. Also, boiler secondary side steam bungs were developed to reduce the time to locate leaking tubes.

d) PHASE 4 (Implementation)

This is when the attention to detail pays off. Through the pre outage period the team would have been split into two groups depending on whether they are to work on the day or night crew during the outage. The crews would have trained together and the team work attitude been well established. Each shift has a coordinator and the original team members play leading roles in the field, often first line supervising the work crews on the job. One key characteristic of the structure is the uncoupling of the coordinator from direct supervision of the activities in the field. The coordinator's role is to look ahead and arrange for upcoming steps, remove obstacles, interact with Planning and Management and redirect resources or change procedures to resolve problems.

e) PHASE 5 (Follow up)

Post outage meetings are held to review the project implementation. Emphasis is placed on identifying actions which will remedy encountered problems with a view to improving performance the next time. The coordinator organizes and expedites the follow up work and storage of equipment and procedures for future use.

One of the challenges of this teamwork strategy is the potential for the team members to encroach upon areas which normally are
the responsibility of one or more of the established station groups. The coordinator is given wide-ranging authority and unavoidably stumbles into areas where others have responsibility.

This can be a problem; however, our experience is that as the effectiveness of this team approach becomes evident to the station departments, they tolerate the intrusions. It helps to have coordinators who are good communicators, to have management reaffirm the role of the team and supervisors who can operate with the team and not react when gray areas of overlapping responsibility are encroached upon. Our experience is that it is possible to have a strong feeling of ownership yet to be effective team players.

4.2 Outage Management

This overall subject has been presented previously in References (2), and (3). The following suggested "good practices" list the maintenance related aspects of outage management which contribute, we believe, to a timely completion of work and good quality of maintenance.

4.2.1 Maintenance Shops Do Assessment of Each Job/Task to be Done. During the pre-outage period, almost as many maintainers are involved in preparing work packages for the outage as are actively maintaining the station. Contractors from the local union halls are used to supplement the crews available to work "on the tools". Each work order is assessed and a complete package identifying the maintenance procedure, parts, tools, scaffolding, etc. is prepared. The packages are usually developed with input from the System Engineer who in turn obtains maintenance input to the work plan when it is required.

4.2.2 Contingency Planning. Jobs are "thought through" with a view to preparing strategy and arranging equipment and resources in case events do not unfold as planned. The SFCR team trained prior to other staff re-inspecting a Pressure Tube with a questionable indication. A helium leak detection procedure was developed in the event that more traditional boiler tube leak detection methods were unsuccessful, etc.

4.2.3 Maintenance Support Equipment Addressed Prior to the Outage. Cranes are inspected, tooling is tested and calibrated, welding equipment is organized and placed local to the job sites, scaffolds and planking are inspected for defects, and then coated with fire retardant paint, etc.

4.2.4 The Plant is Modified to Expedite Work. Cranes and permanent working platforms are added as required, systems are modified to permit jobs to go in parallel rather than in series.
4.2.5 **Pre-Packaging of Work.** As requested by the associated assessment, piping is run and cables pulled ready for tie in, scaffolding installed, parts taken from stores and packaged for each job etc.

4.2.6 **Outage Type Work Only.** All work which can be done on line is excluded from the outage. Considerable effort is taken to ensure that the correct conditions cannot be arranged to complete each prepared job at power.

4.2.7 **Early Freeze Dates on Outage Work.** The station shuts down about mid April. System Engineers begin meeting with Planning in September to identify outage work. Management reviews the proposed jobs and defines the outage scope by January 1. After this point, major work is added to the outage by Plant Managers approval only.

4.2.8 **Maintenance Shops are Involved with the Planning Department in Developing and Reviewing the Logic Diagrams Pertinent to Their Jobs.** Each activity, especially critical path and low float jobs are "critically assessed" with respect to estimated event durations. Correct sequencing of activities and potential interferences are addressed.

4.2.9 **Licensing Issues and Heat Sinks are Rationalized to Optimize Maintenance Flexibility.**

4.2.10 **Radiation Protection Issues are Addressed in the Assessment Stage.** The number of Protection Assistants required to support contractor work and the specific role of the Assistants for each task is defined. Radiation protection safety work plans are developed, specific training provided and equipment procured. Approximately 90% of the maintenance staff are qualified to the green badge (highest) level. An efficient Primary Heat Transport Purification System and attention to the Delayed Neutron and Gaseous Fission Product Systems identifying failed fuel for early removal have kept the shutdown fields low.

4.2.11 **The Outage Management Team is Put in Place Early.** The Outage Manager (a duty Shift Supervisor) and three Outage Coordinators (Senior Operators) are taken off their shift assignments four and two months before the shutdown respectively. This team reviews job plans and job packages and works with Planning to build the outage logic and with the Licensing Group to establish the heat sink criteria. This Operations team also works with the Maintenance Shop and four off-shift outage Permit Coordinators to pre-package work permits for each job.

4.2.12 **Generous Budgets Make the Required Resources (Manpower and Material) Readily Available to Work Crews.**
4.2.13 Liberal Attitude Towards Hiring of Knowledgeable Experts to Support Work Crews in Job Preparation and Implementation. (Refer to 4.1.1).

4.2.14 Use of Skilled Maintenance Staff from Other Company Locations. Fitters from NB Power hydro and fossil stations provide the bulk of the manpower on the turbine/generator maintenance. They bring more experience to this than contractors from the local union halls, have a greater sense of ownership, and, as they return from year to year, they are more familiar with the station, our staff and the way the company operates.

The balance of the maintenance outage staff are tradesmen from the local union halls. A number of people in each trade have been Atomic Radiation Worker qualified through the years.

The "books" generally have sufficient tradesmen to meet any increased requirements during the shutdown with only a few hours notice.

4.2.15 Management Crew Size. The tradesmen from the local union halls and from other NB Power stations come under the direct control of Point Lepreau supervisors. Most of these supervisors, titled Senior Maintainers, are stepped up into the crew leader position for the shutdown and are given a manageable size of crew generally numbering 8 or less. This concept works very well. It permits our people to grow in supervisory experience and provide effective guidance of the tradesmen by one who is very familiar with the station layout, equipment, stores, procedures, safety policies, quality assurance requirements, etc.

4.2.16 The Seniors and Foremen Know the Jobs for Which They are Responsible. The Senior Maintainers (crew leaders) work directly for Shop Foremen. On each of the day and night shifts there are typically 3 Foremen one for each of the Turbine/Generator, Reactor Building/BOP and Special Projects (SFCR, Flux Detector replacement etc.) The Foremen and Seniors know all jobs they are responsible for and thoroughly review the assessed work packages prior to the outage. Furthermore the Senior reviews the jobs, work locations, specific safety/radiation issues and procedures with the off site workers in their crews 1 to 2 days before the actual start of work.

4.2.17 Operations Support is Integrated Into the Maintenance Shops. One Shift Supervisor or Senior Power Plant Operator is assigned to each shop working for the shop supervisors to help achieve their objectives.

This individual performs the following major functions:

- helps expedite work permits and clear permitry problems
- provides Operations and systems knowledge and perspective while problem solving or deciding on best redirection in the light of new or changing information
- helps coordinate the return of maintained equipment in a sequence which is consistent with Operations needs to resupply systems and services

4.2.18 Scheduling Feedback - We actually do know on a given day whether the outage is on time and what activities must be expedited to keep the outage on time.

The progress of each crew is established by obtaining feedback on the status of each activity from the Foremen and Senior Maintainers before 7 a.m. This progress, or lack of it on the major activities, is reviewed by senior site staff at the morning planning meeting at 9 a.m. Redirection of resources and technical discussion of problems are initiated at this time.

The Maintenance Group, Planning and Outage Management senior people meet at the 1 p.m. meeting to further update progress, schedule work for the next 24 hours and arrange for upcoming services from other groups. This is the most significant and detailed of the planning meetings, attended by people "in the know" and by field supervision sufficiently senior in the organization to make things happen.

5.0 CONCLUSION

The strategies outlined in this paper have helped enable the maintenance organization at Point Lepreau to function effectively. We will be challenged in the years to come by aging equipment, a greater rate of staff turnover, the need to retube the reactor, and other issues such as more restrictive limits on the number of overtime hours we can work. Maintaining our fine production records will be a real challenge.

To meet this challenge we must remember what has worked so well for us to date. We must continue to maintain the strong foundations, and strengthen and extend relationships with experienced companies in the Canadian Nuclear Industry. We must expand our project and outage management strategies into new areas. Most of all we must do everything we can to foster the team spirit and feeling of ownership experienced by the people at Lepreau who will make it possible for us to stay "young at heart".
6.0 REFERENCES


"Reaching the Critical Masses"

Honourable Raymond J. Frenette  
Chairman, NB Power

Head table guests, members of the Canadian Nuclear Association, members of the Canadian Nuclear Society, ladies and gentlemen. On behalf of Premier McKenna and the people of the province, it is my pleasure to welcome you to New Brunswick.

As the host utility, NB Power is pleased that the CNA selected New Brunswick for this conference. The last CNA conference held here in 1987 was a resounding success and I am sure this one will be just as rewarding.

Some of you in the audience will be pleased with my next announcement. I am sure that when you came to New Brunswick for this meeting, one issue in particular was on your minds. It is my pleasure to reveal that Premier McKenna has instructed me to announce......

that I should speak for no longer than 20 minutes.

It might not have been exactly what you expected to hear but given your tight schedule over the next two days, I think it is good news none-the-less.

Throughout my almost quarter century in public life, I have always been keenly interested in energy matters.

As Chairman of NB Power, my interest has taken on a new importance and a critical dimension.

One of my goals has been to ensure that the people of New Brunswick understand as much as possible about energy issues.

More specifically, this encompasses everything from the way that electricity is used, through to the different generation options the province has for developments in the future.

As one of Canada's smaller provinces with limited resources, New Brunswick has always had to be prudent with its existing energy sources and forward-thinking with its energy policies.

Everyone has a role to play in the formulation of energy policy because everyone is a stakeholder. This is why it is especially gratifying to see so many teachers in the audience. I know that a portion of the CNA program has been devoted exclusively to energy education.
Indeed, the challenge of educating the public is as important as any technical or scientific challenge in Canada's present-day energy sector.

This educational focus is even more vital in the nuclear industry because, to borrow a phrase and to turn a shameless pun, it means 'reaching the critical masses'.

As many of you know, NB Power is currently considering the construction of a second nuclear unit at Point Lepreau. Too often the public hears or reads about such a project and fails to understand the larger policy context.

In New Brunswick, our objective is to achieve a mix of economic demand-side management programs and supply-side generating projects—this will mean the most reliable service for our customers at the lowest possible rates.

Our discussions with AECL are still at an early stage. However, it appears that a sound basis exists for more detailed discussions and negotiations to proceed.

NB Power will require new base-load generation around the turn of the century or shortly thereafter, depending on our inter-provincial load growth and the development of new external markets.

A CANDU-3 could be an attractive option for meeting these new requirements, if the right combination of risk-sharing between ourselves and the federal government can be established. Our experience with CANDU reactors has been exceptional and around the world the name CANDU is synonymous with superior performance and technology.

There is no question that public opinion will have an influence on our decision whether or not to pursue the CANDU option. Though the average New Brunswicker has some understanding about our energy options, I don't think he or she knows quite enough about nuclear power.

Unfortunately, there are some people who have already formed an opinion against the use of nuclear power and who draw in accurate conclusions from what they know of the facts. They also do their best to muddle the picture for everyone else.

I believe this is where education is the key to the present survival and future prosperity of your industry.

The nuclear industry in Canada has certainly endured its ups-and-downs. In the 1950s, the majority of Canadians not only supported your industry, but it was seen as being synonymous with national pride and progress. By the 1970s, however, support had
fallen to below 50% of the population, and this was even before the Three Mile Island and Chernobyl accidents.

Despite some commendable efforts at correcting the mistaken notions about nuclear energy and making sure that Canadians understood the contributions that the nuclear industry has made to other sectors of society, you have not been able to recover your past position. While the majority of opinion leaders are on your side, most Canadians have not made up their minds about nuclear energy. The jury is still out.

It is clear that this emphasis on education and public opinion is critical.

The wishes of the people will ultimately hold sway. And I know from experience that there is a link between the average citizen's views on energy matters and government policy.

Education is also vital because I believe the more that a person knows about nuclear energy, the more informed and rational their decisions will be. And this means that if a government supports the nuclear option, it can count on the support of a confident public. Any break in that link between knowledgeable citizens and government could have dire consequences for society.

A survey recently undertaken for this conference has shown that while nuclear power is seen by the New Brunswick public as a major source of electricity for Canada in the future, there are still some concerns regarding environmental and safety issues.

The public perception of nuclear energy is linked to concerns about sophisticated technology that are beyond the pale of understanding for average citizens. And the concerns about the potential for damage to humans and the environment are still present even though these risks may be considered quite small.

Nuclear energy is unconsciously associated with fears about the destructive power of the atom and exposure to invisible radiation. In the words of one of your industry's leaders, 'No matter how many years of accident-free operations may be logged, no matter how many hours of nuclear generation there has been, no matter that there has been no serious release of radiation and that in Canada no one has died because of a nuclear-related accident—the fears still exist'.

Nuclear energy has not yet been accepted as commonplace even though nuclear power is as indigenous a resource in Canada as hydropower.

On the surface, I may not have painted a pretty picture. But where others might see only doom and gloom, I think there is
tremendous opportunity for educating the public. I believe the majority of people are somewhere in between the anti-nuclear crowd and the very pro-nuclear. This middle group or the 'critical mass' is your audience. What concerns them is a lack of understanding about nuclear energy and the health and safety issues related to accidents and waste management.

On the positive side, they are also looking for reliable information sources and they are willing to be persuaded.

This being the case, I believe that the focus should be on presenting the nuclear option as an essential one among competing energy sources. The association of nuclear technology with the people who have developed the industry and made it their life's work could also be beneficial.

We have a slight advantage here in New Brunswick. Being relatively small, our utility has a recognizable public face. I would wager that most people in the Saint John area know someone who works at Point Lepreau. New Brunswickers consider NB Power their utility and the people that work for it are their neighbours and friends.

I know that similar ideas on how to sell nuclear energy form the basis of the new strategic plan for the CNA. I welcome and applaud your efforts and I know that they will soon bring results. You may even one day make my job a little easier.

The rewards of your success go far beyond the production of energy. A splendid example already is at work here in New Brunswick.

Maritime Nuclear has shipped $4 million of sophisticated nuclear monitoring equipment to a Westinghouse nuclear power plant in Slovenia. Along with the jobs that such work creates, there is the added benefit of 'the international recognition that is being given a high-tech product conceived, designed, and built here in New Brunswick by New Brunswickers'.

Information programs, long-term efforts in energy education, public participation, and taking account of local interests all are familiar concepts. But they must be tackled again and again, if you are to be successful.

We must remember that, despite some well-known problems, the performance records of nuclear units are not the overriding concern.

Nothing succeeds like success and we have an example of that success right here in New Brunswick. You know about it because it is in your industry, and we are doing our best to make sure that New Brunswickers know about it as well.
Since its first production of electricity in 1982, the Point Lepreau Generating Station has been a world leader in nuclear generating capability.

Nuclear Engineering International has determined that Point Lepreau was first in lifetime performance from September 1982 to September 1991. The results are based on a survey of 350 nuclear reactors in 26 countries. This international recognition reflects the station staff's efforts at achieving and maintaining a superior level of performance in their daily work. New Brunswick is not only able to utilize the best of modern technology, but we set the standard for others in the world to follow.

In conclusion, I can only ask that you maintain your efforts at educating the public about your industry. I am confident that informed members of the public will fairly and reasonably evaluate the facts and ensure that our country will take full advantage of this national expertise. I think that gaining and retaining public confidence will be the most significant factor in the successful continuation of Canada's nuclear power programs. And I include in this list of imperatives any technical or scientific problems that face you today.

In the 1950s our country developed the world's fastest and most advanced jet fighter but the project was ultimately cancelled in part due to a failure to recognize the importance of technical excellence.

What a shame if history repeated itself and Canada has produced the best nuclear reactors in the world and they go the way of the Avro Arrow because of the inability of the public to accept nuclear power.

You know, the most important type of courage is the courage to believe in one's judgement and in one's work. If you believe that your energy resource is the way of the future then you must get out there and sell it.

A wise man once asked his gardener to plant a shrub. The gardener objected that it flowered only once in a hundred years. In that case, said the wise man, you must plant it immediately.

We know that the greatest of all human harvests are the ideas planted and nourished by education, discussion and criticism.

I urge you to plant as many shrubs as quickly as possible so that you may soon reap the rewards of your efforts.

Thank you very much, and I hope you enjoy the rest of the conference.
Mr. Chairman, Distinguished Members of the Canadian Nuclear Association, Ladies and Gentlemen:

I am pleased to have the opportunity to address the Canadian Nuclear Association in my home province and in the constituency I represent in the House of Commons. We are honoured to be hosting members of an association who are recognized as leaders in nuclear technology.

My purpose today is to update you on where we are in nuclear power generation in New Brunswick, and to outline my vision for the future—a vision that can only be realized with your active participation.

It is most appropriate that this is the second occasion for you to hold your annual meeting in New Brunswick—the province which proudly proclaims itself as the home of the world's leading nuclear power plant. One might characterize this meeting as a reunion—a reunion between the world's nuclear industry leaders and the facility that clearly exemplifies the best of nuclear technology.

The members of your association have much of which to be proud. New Brunswick's Point Lepreau Generating Station has demonstrated, year after year, the technical excellence that lay at the very heart of the CANDU system. This is indeed a tribute to the members of your association.

It is your members who can claim the exclusive credit for designing and developing the CANDU technology that has proven itself as second-to-none in the world in terms of reliability, safety and economy of operation.

New Brunswick's world class nuclear power utility is also a testimony to the foresight and to the capabilities of the New Brunswick Electric Power Commission. Increasingly, the world is beating a path to the doorstep of NB Power to seek advice, technical assistance and guidance on the safe and economic operation of nuclear power plants. As most of you are aware, the nuclear experts at NB Power are held in high esteem by their colleagues in your association and, indeed, in the global nuclear power fraternity.
I believe that these two facts—Lepreau being a world class success story and that the province is a nuclear "player"—have created a more positive attitude in New Brunswick about nuclear power.

Let me illustrate by referring to a recent province-wide poll of New Brunswickers.

* The majority (75%) felt that nuclear power will be a major source of electricity in Canada.

* The majority (67%) felt that a second CANDU unit would benefit the New Brunswick economy and the majority (75%) believed that benefits would help more than just the Saint John region.

* There is also evidence of growing support for Lepreau-2: 50% favour, 42% oppose and 8% are undecided.

The attitudinal change implicit in these numbers is most gratifying to me. My personal commitment to Canada's nuclear program and its economically competitive and environmentally sustainable technology goes back many years.

I was a member of the provincial government and cabinet that made the decision to proceed with the province's first nuclear power plant—Lepreau-1—in the early 1970s.

I believed then as I continue to believe now, in the inherent strategic importance of nuclear power for three primary reasons: environmental, economic and security of supply. In fact, my commitment to nuclear energy and its future in New Brunswick may be stronger than any other person outside of AECL and possibly NB Power. That is why the growing support for nuclear generation in New Brunswick is so satisfying to me personally and, quite frankly, provides me with added incentive to continue my efforts to secure an additional nuclear power plant for New Brunswick.

I have been working with AECL and the province for the past six and one half years in an effort to get Lepreau-2 off the ground. I have had tremendous support in this regard from the Saint John Common Council, the Fundy Region Mayor's Association, and the Saint John Board of Trade. In return for this support, I have accelerated my efforts to bring this project forward. But there are limits to what I can do. I am not in a position to render a final decision with regard to a second nuclear plant in New Brunswick. That is a decision for the government of the Province of New Brunswick.

What I can accomplish, and what has been my goal from the beginning, is to support continued discussions between AECL and NB Power. My role is to ensure that the federal government
submits an offer to New Brunswick that the province can accept and that is consistent with the federal government's policy on nuclear development.

We are well on our way to meeting this objective. I am almost in daily contact with my two colleagues: the Minister of Finance and Minister of Energy, Mines and Resources. My discussions with them have been fruitful and positive. I state with some certainty that these two heavyweights think that Lepreau-2 is a project with immense potential. I had hoped to be in a position at this time to witness the signing of a memorandum of agreement on the central principles that will enable AECL and NB Power to enter into detailed negotiations. Although this is not possible yet, there certainly is an air of optimism about the chance of success.

Let me now turn to my vision of the Lepreau-2 project and its strategic significance to Canada, to New Brunswick, and to the Atlantic Region. Lepreau 2 is, by any standards—size of investment, economic impact or wealth creation—a major project. In terms of beneficial and sustainable economic impacts, Lepreau-2 is not just merely another major energy project. Indeed, in a world increasingly concerned about the detrimental environmental impact of thermal power generation, Lepreau-2 could well be the most significant major energy project undertaken in Canada this decade. Lepreau-2 truly represents the opportunity for Canadians to take the next step in the technological evolution of this country's renowned and environmentally sustainable CANDU power generating system. I predict, and I am by no means alone in my expectation, that a successful Lepreau-2 project will open the door to CANDU market opportunities domestically and throughout the world for years to come.

In purely economic terms, Lepreau-2 is a project of major significance through which benefits will flow to virtually every region of Canada. Major beneficiaries, of course, will be Ontario and Quebec. Closer to home, Lepreau-2 has the unquestioned potential to provide a profoundly beneficial impact on New Brunswick and, indeed, on the rest of Atlantic Canada.

It is precisely for this reason and this reason alone that I have so diligently supported this project for so many years. Lepreau-2 has the capability of providing substantial and sustainable technology transfer to the province of New Brunswick, particularly in the fields of:

* Engineering and Design
* Quality Assurance Enhancement
* Component Manufacture
* Modular and Other Advanced Construction Techniques
* Project Management
* Commissioning
* Operator Training
* Simulator and Advanced Control System Technologies

Such transfer in know how and techniques will materially bolster the capability of this region of Canada to compete successfully in a truly global context.

You and I have mutual interests, everyone in this room will benefit if Lepreau-2 proceeds. You know that, and I know that, but let me be clear that my continued support for this project is not without its expectations and requirements. First, you as an industry must weigh in and support my efforts and the efforts of my colleagues, such as Don Lawson at AECL, to get this project underway. You must become actively involved in ensuring that all levels of government are seized with and understand the opportunities and the potential of this project.

I invite all of you here today, you will benefit from this project, to put your shoulder to the wheel and help us make it happen.

Secondly, and let me be very clear on this point, from our perspective here in New Brunswick, Lepreau-2 cannot be just another "love them and leave them" project. For this project to proceed, there has to be a desire, a will, indeed a demonstrable commitment from all participants in the project to make New Brunswick a focus and centre of excellence for AECL CANDU's new CANDU-3 power reactor system. Decisions must be taken to assure that, during project planning and implementation, all possible steps are taken and initiatives launched to secure this goal.

While I can do everything in my power to ensure that the federal offer to New Brunswick is as attractive as possible, as I have already said, the final decision, of course, rests with the New Brunswick Electric Power Commission and the provincial government. But let me assure you that we in New Brunswick share a common view that Lepreau-2 must, in every possible way, provide the fullest range of sustainable economic benefits to the province of New Brunswick and to Atlantic Canada. Let me assure you that nothing less will do. So, it is up to you here today to roll up your sleeves and get behind this magnificent opportunity, both in terms of active advocacy for the project and in assuring its sustainable economic impacts.

You have my commitment to continue to work tirelessly with you to see that Lepreau-2 becomes a reality. Equally, I trust that I have your commitment to deliver on my expectations and, quite frankly, the legitimate expectations of the people of New Brunswick.

Today, an opportunity presents itself—a CANDU-3 reactor at Point Lepreau—that if realized will provide lasting economic
development to Atlantic Canada and offer your member organizations the chance to be fully engaged in its development and construction. It would not be an exaggeration to state that Lepreau-2 promises to be the most significant energy project to be developed in Canada for the next decade. With its economic benefits and environmentally sustainable technology, the CANDU-3 would find its ideal home in New Brunswick. Let us work together, with patience, diligence and clarity of purpose to ensure that the Lepreau-2 opportunity is not lost. We owe this to ourselves, but most important, we owe this to our children whose innocence demands that we bequeath them a world with a secure energy future and a clean environment in which to realize their dreams.

Thank you.
COUNTERTRADE AS A MARKETING AND FINANCING INSTRUMENT FOR EAST EUROPEAN BUSINESS

Challenges, problems and opportunities of non-conventional export promotion and export financing in the wake of political and economic upheaval in Eastern Europe

Preliminary remarks

I. Economic consequences of the political changes

II. Consequences for the financing of East European business deals

III. Export promotion and export financing through countertrade

IV. Countertrade tools

V. Possible types of countertrade in the current economic environment

VI. Establishment of a realistic framework for success of export transactions according to regions, size and personal requirements

VII. Problems and risks associated with transactions - experience of negotiations

VIII. Safeguarding of interests through appropriate structuring and supervision of the transaction

IX. Special features of individual markets and comparison between countries.

X. Outlook and future perspectives
Preliminary remarks

- The political changes

- Emergence of new, independent states in the Baltic Region, Lithuania, Latvia, Estonia

- The 11 states of the CIS (22.12.1991) Pro- and anti-Russian camps (Ukraine, Moldavia, Aserbaidzhan, Tschetschenians, Tatares)

- Political independence and decentralization following the collapse of the Soviet Union

- Continuation of the strive for political autonomy

- Discrepancy between the general desire for reform and preparedness for radical reforms

- Illusionary expectations as to dimensions as well as time and geopolitical implications

I. Economic consequences of the political changes

Objectives of reform

- From state planning committees to reforms and new organizational structures

- Dismantling of state monopolies

- From political decentralization to economic restructuring

- From planned economy to the market economy

- Removal of state subsidies

- Liberalization of economic relations
- Price liberalization
- Modernization of plant facilities and systems
- From state ownership to private ownership
  - Micro economic level: slow process
  - Macro economic level: innumerable obstacles
- Free competition
- New enterprises, culture, management
- Land reform
- Liberalization of foreign trade
- Financial policy and convertibility of currencies
- Building-up of an efficient finance sector
- Banking system
- Fiscal reforms
- Prudent income policy
- Building-up of a social network

Obstacles, reflections and current reactions to the targets and objectives of reforms

- The more radical the process of transformation the more negative are influences on industrial production
- Serious decline of industrial outputs
- Shock of the collapse of COMECON
- Cut of business links likely to accelerate further market disintegration
- Lack of competitiveness in the world market. Better opportunities within "internal" markets

- Lack of appreciation of the essential elements of the free market economy such as:
  
  free competition
  
  private ownership and management
  
  functioning capital markets
  
  money policies and free convertibility of currencies
  
  independent autonomous and fully responsible business enterprises
  
  removal of subsidies
  
  lifting of price controls

- The more chaotic the situation develops, the greater the danger of bureaucratic intervention

- Lack of ideas and concepts for instigating reforms

- Limitation to basic decisions with hesitant and half-hearted implementation

- Political responsibility and economic ownership remaining with representatives of the old political and central authorities

- Management without market experience and without international contacts; uncertain, overcharged and incapable to manage economy according to requirements of a free market economy
Land reforms planned and partially imposed. Ideas about implementation procedures, however, missing. Very few of stated intentions and concepts see the light of day (CIS) in practical implementations.

- Financial policy as a monopoly of the Russian Republic (CIS)

- Impossibility of political stability, if member states of the CIS remain dependent on the State Bank of one Republic

- Run away from Rubel as a threat to convertibility. Dollarisation of the economy.

- Privatisation legislation remains a fundamental concept of the CIS but regulations to put it into practice are lacking. So far only profitable activities were privatized. Transfer to "old comrades"

Social environment

- Problem: Motivation and readiness for reform. Lacking or merely hesitant desire for reform. Dwindling acceptance of reform

- CIS: more than 50% of the population below the minimum conditions

- Reduction in the real value of income

- Bottleneck in the supply of all foodstuffs

- Need to safeguard daily living for individuals and families becoming breeding ground for bribery and corruption.

- Accumulated needs to enjoy freedom and to satisfy interest in more valuable living and free travel

- Overspeeded and exaggerated corrective and defensive measures by unprepared governments:
restrictive economic policies for the purpose of stabilizing the economy

- Establishment of new customs frontiers

- Introduction of export restrictions

- False endeavours towards self-sufficiency

- Cut of grown traditional market ties

- Compensation of serious price increases through increases of wages and salaries

- Consequence: Wage/price spiral. From inflation to hyperinflation

- Negligence of obsolete production plants, lack of readiness to invest in replacement or rehabilitation and revamping

- Attempt to squeeze earnings from the only high-tech sector (military sector) by setting technology equipment and weapons.

- Disposal of nuclear raw material and technology to politically volatile countries (Lybia, Iran, Iraq, Pakistan) only in the interest of obtaining foreign currency

**Solutions and necessities**

- In view of the enormous backlog demand in priority sectors such as agriculture, energy, consumer goods, communication, transport and environmental protection the following actions are essential:

  - Broad management and entrepreneurial commitment

  - Massive western support, financially, technologically and human resource wise
- Intensification of product exchange with the aid of non-conventional trade and finance practices
- Collaboration in the reconstruction of a common market (East European - ECC)
- Investments, joint ventures, large scale industrial cooperations

II. Consequences for financing

- Increasing indebteness in major countries (chart of indebteness of the former COMECON countries).
- Rising inflation
- Budget deficits in GDP with decline in industrial output
- High risk exposure and accumulating risk factors:
  - Credit risks
  - Insufficient credibility and financial standing of enterprises, commercial banks and national banks
  - Lack of information systems for economic data
  - Construction and development risks due to material defects, transport difficulties, time delays
  - Operational risks due to obsolete technology and overaged plants and equipment as well as worker attitudes and working mentalities
  - Financial risks due to price fluctuations, interest fluctuations, inflation, protectionism and custom tariffs
III. Export promotion and export financing through countertrade

**Export promotion**

- Countertrade as sales support
- Additional benefits for the customer
- Attractive features against competition
- Market integration
- Identification with the purchasing country
- Customer as longterm partner
- Longterm advantages und expectations

**Export financing**

- Generation of foreign exchange
- Full- or part financing of an non-export risk insured transaction
- Generating of the means for the down payment
- Security of the separated means and their protection against the intervention of third parties
- Use as guarantee for creditors in traditional financing
- Structuring according to and in dependence of kind and payment conditions of the export business
IV. The Countertrade tools

- Barter
- Compensations
- Parallel Purchases
- Buy-backs
- Build-operate and transfer (BOT) models
- Leasing business in connection with "buy-backs"
- Pre-purchases
- Escrow accounts
- Maximization of local content
- Bilateral trade agreements
- Evidence accounts
- Clearing accords with switch-potential
- Offset
  - Direct and indirect offsets

Characteristic features of countertrade in the past

- Long tradition
- Established structures
- Product monopolies
- The role of foreign trade organisations (FTO's)
- Known trade rules and practices
- Stereotype contractual arrangements and forms
- Established negotiation procedures
- Contract conform execution
- Availability of products for export
Free choice of foreign trade organisations and products
- Liberal attitude towards execution through third parties
- Few market restrictions
- Countertrade quotas up to 100 %. Exception: Romania
- Acceptable time span for execution
- Tolerable quality standards
- Established penalty schemes with room to negotiate

Today's current countertrade situation
- Increasing pressure to apply countertrade in view of:
  - Lack of foreign exchange
  - Lack of traditional credits
  - Lack of aid funds with soft terms
- Limiting conditions and boundaries
- Bilateralization
- Abolishment of product monopolies
- Dissolution of foreign trade organisations. Change of their modus operandi
- Integration in production plants
- "Provincialisation" and "Balkanisation"
- Lack of sufficient knowledge by partners of export marketing and countertrade mechanism
- Uncertainty in the execution of contracts
- Deteriorating product qualities, increasing claims with corresponding damage risks
- Reduced availability of products
- Limitations to free choice of products and markets
- Additionality requirements
- Inclusion and coverage of financial costs
- Reduced execution periods together with limited offers of products and services
- Pressure on pre-purchases and all kinds of advanced commitments
- Desire for cooperation and technology transfer
- Escrow accounts in third countries. Return of money into the export country
- Implications for export business due to contractual difficulties in countertrade on the import side
- Reduction fulfilment possibilities
- Call for customised solutions with high degree of creativity
- Increased cost of execution
- Trend of rising subsidy fees

V. Reduction of the countertrade instruments to some possible forms in today's economic environment

- Barters
- Compensations
- Pre-purchases
- Parallel purchases
- Bilateral trade agreements
- Buy-backs from joint ventures and technology transfer
- BOT-models

6. Definition of realistic parameters for implementation

Industrial areas and dimensions

- Not suitable for: projects relating to heavy industry, large infrastructure projects, mining, capital intensive industries

- Preferred: agriculture and farming, light industry, consumer goods, oil exploration, construction industry and construction products, hotel industry, office building, pharmaceutical industries, medical and diagnostic instruments, foodstuffs, equipment for storage and transport, children's foodstuffs, diabetic foodstuffs, durable consumer goods, transportation, energy-saving, tourism.

Target projects

- Project size of US $ 100 Mio. and above prove to be very difficult.

More appropriate:

- Sales business in approx. amounts of US $ 1 - 10 mio.

- Business transactions should rather be of a testing nature for markets, business climate, economic and industrial framework and partner
Requirements

- Enterpreneurial commitment and readiness for limited capital investment
- Readiness to be physically present in the country with language and cultural knowledge
- Required are: "Doers" ("get out and do")
- Time for first small steps now into the private sector
- Highly risky and considerably more difficult: big steps into business with governments and states
- Result: three possible enterpreneurial profiles

a) Investor with longterm perspective and the readiness to utilize longterm potential in the country, to earn local currency and to re-invest. (Agricultural business with "buy-backs") Investor who brings in know-how and technology in joint venture with local partner. Local partner who makes available real estate und production equipment. Afterwards sales of the products on the world market. Requirement for business to be transacted in local currency however: small scale and limited risk.

b) Investor in projects where foreign exchange is already available today (hotels, restaurants, office buildings and services for foreigners).

c) Services for foreigners and limited room advice to nationals.
VII. Problems and risks of transactions

- Quality of products
- Marketable goods "sold out"
- Exaggerated price philosophy
- Noncompliance with delivery dates
- "Linkage"-problems
- Conditions for approval and export licences
- Expectation of special advantages to companies and individuals
- Influence of heterogeneous interests
- Problems of "local content"

Negotiation experiences

- General insecurity resulting from legal situations which are unclear (crash programs)
- Non-defined competences
- Lack of negotiating competences and power struggle between enterprises, local governments regional authorities and national ministries
- Laws raise more questions than they answer
- Definitions and rules are incomplete equivocal, sometimes contradictory
- Lack of execution regulations
Laws and regulations have to be first qualitatively tested in practice as they come from ministries and legislative bodies without experience of the capitalist economic environment.

- Considerable cultural differences
- Lack of language knowledge
- Legal-profession not qualified or not familiar with the new legislated issues
- Western legal systems, jurisdiction principles and methods of law application unknown
- Contractual negotiations considerably longer and less calculable than in the West
- Spirit of socialist command economy still very strong
- Lack of experience, qualification and longterm commitment in and to managerial responsibility
- Lack of criteria for measuring diligence, no means of sanction for diligence violations
- Non-availability of information concerning the enterprises, their market and their business prospects
- Unreliability of available data
- Lack of reliable operational information and detailed cost analysis
- Lack of profit and loss accounts as well as inventories (i.e. details of assets and liabilities)
- Trade receivables at best registered but not recoverable
- No reserves for dubious positions
- Reservations, fear, discouragement and lack of candour in the management (old hierarchy)
- Absorption of management energy by private living and supply problems
- No overview of commercial and technical connections and their interdependence operation and lack of readiness to become involved in complex multi-facet and interconnected issues.
- Lack of ability to follow-up and control
- Advice: Nothing can be taken for granted. Obvious things have to be explained. The western partner is at the same time missionary, teacher and business partner.

VIII. Safeguarding of interests through appropriate structuring and supervision of implementation and execution

- Continuation of high risk inclination of main export and countertrade transactions ("force majeure", power supplies, transport, conflicts of competence)
- Entrepreneurial commitment to the EE export market and direct assumption of influence on risk factors is not only an economic but also a political decision
- Measures to reduce risk
  - appropriate project size
  - appropriately short realization time
  - local presence and on site inspection
  - Securing of communication
- Identification of the countertrade goods with preference of raw materials and semi-finished products whilst avoiding finished products in the initial phase

- Verification of approval requirements in the export and import country

- Own entrepreneurial commitment to joint ventures or cooperation projects. To leave as little as possible organisational authority and initiative exclusively to the Eastern partner on site

- Quality assurance of countertrade goods by way of technology transfer, know-how transfer, technical and commercial assistance

- Control of production and dispatch at regular intervals

- Critical check of the transport routes and means of transport

- Steady influence on delivery planning and control of delivery times

- Arrangement of an "escrow account" outside the country

- Pre-purchases and sales transactions as coverage of deliveries and/or production risks

- Complete, accurate and precise contracts

- Agreement on legal consequences in the event of non-compliance and non-delivery

- Agreement to all other sanctions in case of non-compliance with contractual regulations
- Check of private insurance possibilities for certain risks, however with high cost implications

- Letters of credit are only valuable as security of payment if they are not issued by the Vnesheconombank, but by the foreign-trade banks of the individual Republic which are currently being set up.

- Increased risk with progressive level of finish of countertrade goods. Increased prudence with finished products

- Increased risk through long distance transport routes leading through several states or autonomous regions

- If countertrade for financing of the total transaction is not possible or sufficient, check for countertrade transactions to mount for payments or non-export insured parts of the business

- Possibility of countertrade transactions as basic security for Western bank creditors

IX. Special features of individual markets and national comparisons from the point of view of financing and countertrade

Group 1: middle European states with visible reform progress, with comparably greater stability and long term positive economic indicators:

- Hungary

- CSFR

- Poland

- Countertrade practically not promotable or achievable via state institutions
Countertrade for the time being only possible on an ad hoc basis, if partner disposes of own products for countertrade transactions.

Countries in the long term inclined towards offset policies.

**Group 2:** CIS states, disposing of strengths for future continuous economic growth through the following factors and elements:

- Agricultural production (self sufficiency)
- Degree of industrialization
- Infrastructure
- Raw materials
- Attitude towards free market economy and resulting systems

The following countries belonging to this group:

- Russia
- Ukraine
- Belorussia
- Kazakhstan

Countertrade is partly still possible through state-run central institutions if strategic products are under clearance.
**Group 3: Baltic States:**

- Estonia
- Latvia
- Lithuania

This group lacks raw materials but has a certain level of industrialization and a high standard of education. It profits from the geographical position, neighbouring states connections, languages etc. but needs the market of CIS Republics for sales.

Countertrade predominantly bilateral between the participating contractual parties. In the long term chance for offset arrangements (Estonia).

**Group 4: Countries of the ECO group:**

- In the "Organisation for Economic Cooperation" approaches by the individual islamic Republics:
  - Aserbaidzhan
  - Turkmenistan
  - Uzbekistan
  - Tajikistan
  - Kirghizia

with fraternal islamic countries of international weight:
- Iran
- Pakistan
- Turkey
with present tendency favouring Turkey. Conclusion of bilateral trade agreements. In their wake revival of switch business seems possible.

Group 5:

- Economically weak countries with obsolete structures still under the strong influence of the old planned economy.
  - Bulgaria
  - Romania
  - Albania

Potential can only be activated in the long term. By contrast, opportunities for compensations still available. However, terminology ideologically burdened, (Romania).

X. Outlook and future perspectives

- Increasing financial problems, gaps and bottlenecks
- Growing importance of countertrade for the project acquisition and project realization
- Increasing pressure for reciprocity in trade connections
- Countertrade in medium-term; but offset only relevant in the long-term
- Types of countertrade currently significant:
  - Barter
  - Bilateral counterpurchase
  - Pre-purchases with escrow account
- Buy-backs also in connection with leasing
- Local content in project realization
- Cooperation with multiple exchange of products and services
- Occasional switch operations
- Significant in the medium term:
  - Parallel purchases
  - Direct offset
- Relevance long term:
  - Indirect offset

No longer significant:
- Junktims
- "Countertrade credit trade"
- Evidence accounts
- Penalties