# PLM AND THE SINGLE REACTOR UTILITY

## *OR HOW A SINGLE REACTOR UTILITY CAN FACE THE PLM ISSUES*

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## INTRODUCTION

Ageing is a phenomenon that no one can escape, not even a high-tech nuclear generating station. There are many aspects and many issues to cope with when a utility considers a station plant life management (PLM) program : economics, nuclear safety, technical assessment, knowledge and know-how.

To maintain the long-term availability and capacity factor with controlled and reasonable generating costs during the whole service life is a prime concern. Safety is also a major issue. The deterioration, with time, of the safety level and the rise of uncertainty with regard to safety are real concerns.

A single reactor utility has much to gain in seeking cooperation, in order to share its limited experience and resources with others. Also, it may be wise to go one step at a time along the road to life extension.

## 1. AGEING

***Getting Old***
*ageing should receive early attention*

Equipment performance, station reliability and capacity factor are expected to drop during the late middle and latter years of a nuclear station nominal life.

Different degradation mechanisms may affect the systems, structures and components (SSC's) to such an extent that they may not fulfill adequately their function anymore. This is based on their design, manufacture and installation, but also on the conditions in which they have been operated and maintained. Their impact on station life is related to the difficulties to repair or replace them. They may also become obsolete and no longer fulfill their mission.

Ageing mechanism will manifest itself, with time, in functionality and performance. Factors that affect SSC's can be fatigue, wear, temperature, humidity, pressure, chemistry variables, vibration, flow erosion and corrosion, neutron bombardment, gamma radiation, etc. Ageing mechanisms begin to take their toll on components from the very moment they are delivered, even before plant construction.

IAEA defines ageing as a "continuous degradation of components, systems, structures resulting from cumulative changes with time under normal service conditions, including normal operation and transient conditions". This degradation can hit material property and/or functional capability.

It is believed that ageing issues and their impact on the nuclear station's reliability should receive early attention in the station's life so that proper planning and proactive maintenance and programs can be put forward to manage the effects of age related degradation.

One of the main features of a plant life management program is to demonstrate that the stresses of time have not degraded the physical conditions of the station, especially the passive SSC's. The most vulnerable SSC's beyond 40 years of operation seem to make an increasingly large consensus. They are the containment, the concrete structures, the pressure tubes, the supports, the steam generators, the piping and the cabling.

### ***Any Signs that Gentilly 2 is Turning into an Old Folk?***
*pressure tubes may force the station into premature shutdown*

The design life of our pressures tubes is 210,000 hours at 100% FP or 30 years at 80% capacity factor. This is significantly less than the nominal 40 years for the reactor pressure vessels of the light water reactors. This introduces, up front, a different perspective to life management.

Candu-6 pressure tubes seem to have a good tolerance to flaws, debris fretting, fuelling scratches, crevice corrosion, fuel bearing pad fret marks or manufacturing flaws both in the body of the pressure tube and the rolled joint.

However, they are prone to hydride blister formation for pressure tubes in contact with the calandria tubes and with hydrogen equivalent level greater than the blister formation threshold at contact location. The current strategy for fuel channel maintenance and inspection addresses adequately this major issue.

Also, pressure tube material properties change in-service. The present evaluation of integrity using the current data shows adequate safety margins even though fracture toughness may decrease faster than predicted and may remain a concern. Recent data shows that deuterium pickup is higher than expected. This may alter the leak-before-break criteria. It may prove to be a life limiting factor or require, in the distant future, a prohibitive amount of in-service inspection.

In the long run, dimensional changes may prove to be the pressure tubes' life limiting factor. Monitoring, to date, of axial elongation has shown that the fastest growing tubes could run out of bearing travel before the end of their design life. Engineered solutions could offset this dimensional change. Diametrical expansion is within the value assumed in the design analysis. This dimensional change may bring reactor derating at the end of service life, due to bad erosion of operating margins caused by trip setpoint penalties. Remedies may exist to offset this. Pressure tube fuel channel sag can lead to several limits that could be reached before the end of design life : contact with horizontal mechanisms, contact between pressure tube and calandria tube, and fuel bundle pressure tube interference. This is not a big concern, but still a concern.

We already know at lot of things about pressure tubes through the R & D programs and the station inspection programs, but there is still a lot to be done. Hopefully, we will eventually identify the life limiting mechanisms and conditions for our station, and count on good and reliable life indicators.

In any case, pressure tubes may force the station into premature shutdown, because there is still so much uncertainty on many aspects, in spite of very significant R & D and inspection efforts.

Other station early ageing signs: tighter margins on the regional overpower trip setpoints, practically no margin left on the inlet header temperature (increasing primary side and secondary side fouling in the steam generators), increasing containment leak rate, increasing corrective maintenance rate for the important valves on the heat transport system, general wear as measured by the increase in the cobalt radiation field from the heat transport system, etc. ...

On the other hand, our steam generators have not shown any signs of degradation so far. They seem to be in excellent condition and the very few tubes that have been plugged are those that have been taken out for destructive examination.

## ***AECB Generic Action Item***
*to provide the assurance of continuing station safety*

On October 4, 1990 the Atomic Energy Control Board (AECB) sent us a letter about the assurance of continuing nuclear station safety. This is now known as Generic Action Item No 90-G-03. Figure-1 introduces some of the key words on that issue: "physical changes with time, age, not compromising safety, remain assured of future safety, ..."

This generic action item expresses the well-founded concern that safety-related SSC's may become less reliable with time. The effects of ageing may eventually challenge the design safety margins, if not detected nor corrected.

This issue is twofold: the assurance that the physical changes affecting the SSC's are not compromising their functional ability to perform their safety task, and the assurance that these physical changes are not compromising the safety analyses themselves.

To provide this assurance of continuing nuclear station safety to ourselves and to the regulator, a variety of ageing management activities and programs are performed over the life cycle of the station in order to anticipate, detect, prevent, correct and mitigate the effects of ageing.

## 2. THE PLM OPTIONS

*to retub or not to retub, that is the question*

### ***The Do-Nothing Option***

*the original investment at risk*

The do-nothing option does not mean that we are actually to do nothing. On the contrary, we would try to get as high a return as possible out of the original investment in the station. This station is amortized over a 30-year period, so we would try to get 30 years of production out of it, while keeping O & M costs as low as possible.

The do-nothing projection reveals that availability would most probably decrease significantly if no special action is taken. Even for a patch and run program, the station would only barely maintain a 60% level of availability during the last years of operation. And the cost of a patch and run maintenance program would skyrocket to a point where it would be so prohibitive that we would most probably shut the station down prematurely, say after 27 years of operation, to be optimistic.

This is well illustrated in figure-2. The 80% capacity factor is the design target. The reversed bath tube shape curve is what one would normally expect. The solid line curve is what would most probably happen. The left hand side curve is what one wants to avoid but is hanging over his head if maintenance is neglected.

There is a definite possibility that the do-nothing option will not allow a maximum return on investment, nor will it protect the original investment.

### ***The Life-Assurance Option***

*a life-time capacity factor enhancer*

The life-assurance option is the very first objective of a plant life management program. It is aimed at getting the expected return on the original investment, i.e. first, to get to the end of the station design life of 30 years and, second, to maintain the capacity factor as high as possible while keeping the station safe.

The life-assurance option is designed to keep a good record as far as electric production and nuclear safety are concerned, to avoid any station early retirement because we have neglected maintenance or have not been using the right maintenance programs or the proper operation methods.

Also, this option should provide the utility with a reasonable assurance against any unexpected "catastrophe" or any unforeseen major flaw or disruptive event that may be station-life threatening or overly costly, such as having to replace the steam generators without warning and having to undergo a two-year station outage because there would be no replacement generators available.

This option should also allow us to be ready far ahead of time, just in case something dramatic happens to the pressure tubes before the end of their design life.

This option should allow us to set long-term performance-based goals for critical and for important SSC's, and to document that the SSC's are meeting their goals with either the existing or corrected maintenance programs or with modified operation methods. To do so, nearly the same assessment studies as for the life-extension option would have to be performed.

Gain on the capacity factor (and on the return on investment) should be at hand as illustrated in figure-3. Not only should the station avoid premature shutdown, but this option should allow for a substantial increase in the capacity factor during the last ten years of design life.

### ***The Life-Extension Option***
*a lucrative cpportunity*

As it is not clear that we may operate our station for even its total design life without having to replace the pressure tubes, the life-extension option means for us a scenario where, during a prolonged shutdown, reactor retubing and station refurbishment take place after, say 25 years of operation, and station life is extended for say another 20 to 25 years, for a total service life of 45 to 50 years. This is not much more than the expected 40-year "design life" of the US or French reactors or much more than the expected 40-year "strategic life" of the CANDU stations in Ontario.

For the foreseeable future, technical obsolescence would probably not affect the CANDU-6 stations because they are of a generation of relatively mature commercial power plants with a high basic safety level. On the other hand, even though there are significant pressures to ever increase the level of safety, there is now a tendency to slow down the rate of increase throughout the world.

To maintain the life extension potential of the station, studies and vigorous implementation of their recommendations would contribute to improve or maintain production reliability, to enhance or maintain safety margins and to provide greater assurance that the design operating period can be achieved.

The life-extension option, as shown in figure-4, would also secure THE only nuclear site qualified in Québec and the nuclear option open within the utility.

## ***Geriatrics***
*the international experience*

Almost every country where there are operating reactors has an ageing and plant life management program of some sort aimed at determining the safety, economical and technical feasibility of continued station operation while maintaining or improving safety, availability and O & M costs. Most of these programs seek to identify and better understand ageing mechanisms and the necessary mitigating measures.

In the *United States of America*, DOE and EPRI have demonstrated, back in 1984, that it was economically profitable to invest in license renewal and life extension of nuclear plants; the License Renewal exercise with the two lead plants (Surry and Monticello) has demonstrated, as early as 1987, the feasibility of life extension up to 70 years for essential SSC's (with some replacement and repairs); since then, there has been a blockage of the process between NRC and the utilities.

Nevertheless, the NRC NPAR (Nuclear Plant Ageing Research) phase II program is still moving ahead and, in the US, the odds are that most stations will continue to operate through their first 40 years, as a minimum.

A few years ago, the life extension road appeared relatively straightforward but license renewal has taken unexpected turns in the last two years. The American utilities (Virginia Power, for example) now talk about plans to apply for a five-year license renewal instead of 20 years; on the other hand, instead of going for lead plants, they may go for a more generic approach with the Owners Groups.

*Électricité de France* (EDF) has had a Life Management Project ("Projet Durée de Vie") since 1985; this project studied eighteen essential SSC's and concluded in the "Rapports de Constats", the topical reports, that the technical potential for life extension to 50 years or more was excellent. In addition, seven generic studies have been done on the degradation phenomenon or technique, such as vibration, fatigue, bimetal joints, ... The program is completed by an evaluation of out-of-service equipment such as the Dampierre steam generators or the Chooz A reactor pressure vessel.

EDF expects to run its PWR's for at least 35 years and up to 40, 50 and maybe even 60 years. So far, the reactor lifetime limiting factor is the reactor vessel embrittlement.

The "Projet Durée de Vie" also deals with aspects such as: economic competitiveness of extended life plants (O & M costs and refurbishment costs) with other energy sources. Under basic assumptions, it looks like there may be adequate margins. The project also tackles issues, such as safety and licensing, that may prove to be bothersome if the reference licensing basis is shifting too much. It also takes into account the production system and grid renewal as well as the industrial context.

*Ontario Hydro* has almost completed the scoping phase of its Nuclear Plant Life Assurance (NPLA) program started in 1987. The goal of the program is "to improve plant productivity in the longer term by improving maintenance to offset the effects of plant ageing". The program aims at providing 40 years of station service life, avoiding major surprise failures and preserving the option of life extension beyond the assumed nominal service life (40 years). To achieve this goal, the program has developed a basis for operation, inspection and maintenance of the critical components (with respect to cost, safety or reliability) and for managing the effects of ageing. The program also has the objective of making sure that all relevant activities are part of an overall plan. While the US PLEX program is mainly driven by licensing considerations, the Ontario Hydro NPLA program emphasises reliability of operation.

The *OECD Nuclear Energy Agency* PLIM Group was created in 1990 to achieve a systematic and high level of collaboration between the many different countries involved in these issues of ageing and life management. They have identified a model PLM program composed of many elements related to sound management, technical issues, safety issues and economic issues. Also, an *IAEA* NPP Ageing Program has been in existence since 1985.

## 3. THE PLM FEATURES

*looking for the show-stopper*

International studies over the last five years or so have demonstrated that there is probably no such thing as a single component being life limiting to the station; for example, CANDU reactors have been fully retubed, steam generators are being replaced, and studies show that a light water reactor pressure vessel can be replaced at a cost lower than steam generator replacement.

In the US, the expected service life is 40 years for BWRs and PWRs; in France, it is 40 years for PWRs; in Ontario, it is 40 years for CANDU stations. Design service life and the financial amortization period for the Gentilly 2 station is 30 years. With a full reactor core retubing, there is, at minimum, a very real potential for life extension from 30 to 40 years!

### *Economic*

*a steam generator replacement for every three years of extended life*

The optimum service life of Gentilly 2 has to be assessed in relation with the Hydro-Québec system, existing and planned. This is not an easy task because of the very high complexity of the network, the very long time frame involved in the planning and basic uncertainties about the future.

Nevertheless, a very preliminary exercise has been performed. This preliminary estimate was not based on the insertion of the extended service life of Gentilly 2 in the planning of a new generation program, thus displacing or postponing the construction of new equipment. The calculation was based on the value of the energy and power at system marginal cost in the existing generation mix versus the production cost. It is the calculation of revenues versus investment and O & M costs. It is a comparison between the value of the service (energy and power) to the grid and the cost of maintaining the station in operation.

The results of this exercise are very encouraging. According to the current reference scenario calling for station retubing and refurbishment after 25 years of operation, less than 15 years of extended service life would be necessary to justify the investment, for a total service life of less than 40 years. Any operation beyond that point would be highly profitable. In fact, these preliminary results show, for example, that a steam generator replacement could be affordable for every three years of prolonged service life.

These results are good enough to carry on with the studies in greater details. Cost/benefit analysis has to be fed back into the generation planning model to determine if routine O & M costs, exceptional maintenance costs, such as replacement or modifications imposed by safety or availability requirements, on top of the capital spending associated with the refurbishment needed for life extension, are justified in comparison to other energy options.

For the time being, it is thought that station life extension (beyond 27 or 30 years) expenditures are a justifiable and competitive alternative to new station construction including site approval.

In any case, the length of our station life will be a "business decision".

***Safety***
*cost-benefit criteria should be introduced in regulatory decision making*

Safety should be a major feature in any plant life management program. The deterioration with time of the safety level and the raise of uncertainty in safety are real concerns. Demonstration has to be made that the station is still always as safe i.e. maintaining its current level of safety.

However it should be accepted that the station has to comply with its original licensing basis. Older stations should not be asked to comply with later standards and undertake massive backfits.

It should be basic common sense that a station that has operated for twenty years or more with an excellent operational safety record should be credited for this achievement and not be asked to satisfy the same criteria as newer stations. A station that was safe on its twenty-fourth year of operation will not suddenly become unsafe, overnight, on its twenty-fifth year.

Of course, we should be ready to evolve with the tools, methods and criteria used to reassess the safety of the station on an ongoing basis. Although this evolution may bring some adjustments or modifications to the SSC's, it should not lead to radical questioning because the CANDU-6 design is still very current.

The judgment as to wether the current safety level is enough should be based on a criteria measuring the gain in safety against cost. Cost-benefit criteria should be introduced in AECB regulatory decision making. One should not spend considerable amounts of capital on supposed low probability accident situations. For example, a difference between costs and supposed benefits of two orders of magnitude should be considered sufficient to eliminate any further consideration of the degree of uncertainty in any analysis. Utilities do not want to play fast and loose with safety, but they do not want to misappropriate public funds either.

All together, we must find a reasonable way to slow down the actual inclination of our regulator to have unduly high requirements. These ever increasing requirements can be found in the protection against serious accidents such as in the Secondary Side Break Accident or in the protection against external attacks such as floods and earthquakes, or in the future as demonstrated by the C-6 Requirements for the Safety Analysis of CANDU Nuclear Power Plants or the C-98 Reliability Requirements. These new requirements are far from the original licensing basis and, moreover, would have very little net benefit for the safe operation of the station, while introducing a very significant financial overburden in analysis and modifications.

In extreme cases, over-regulation or undue requirements by regulatory agencies can become counterproductive even with respect to safety. For example, the existence of undue restrictions in the accreditation of senior operating personnel may mobilize all the training resources, thus jeopardizing all other personnel training or, in effect, depriving the utility of essential technical resources. Indeed, by remaining at the helm of the operation too long, authorized senior operating staff run the risk of getting "stuck on shift" while waiting for their successors to take over. This, in turn, keeps their experience from being put to the best use, i.e. serving safety.

Cost-related premature shutdowns are likely to become an issue if one has to navigate the uncertainties brought on by the regulator's ever changing rules. We are confronted with a technology killer here.

Moreover, public attitudes towards ageing nuclear stations and public feelings towards the nuclear industry in the years 2010-2020 may eventually be key in terms of gaining public acceptance for continued or extended operation. Safety issues should be addressed in a transparent way and the solution readily understandable. An open dialogue on the impacts of continued operation versus other energy options should be promoted.

Ultimately, one of the best ways to deal with the safety issue would be to establish a constructive day-to-day dialogue with the regulator and help him regain trust in the utilities. With that trust we would show them that, for us, good safety is good business.

***Technical Assessment***
*the non-committing aspect of PLM*

Technical SSC's life assessment requires:

- the knowledge of the actual conditions (including transients) in which the components operated;

- the verification that these conditions and their associated degradation mechanisms are compatible with the design envelopes or hypotheses;

- the definition of functional life indicators or the identification of margins left, or remaining service life.

The technical assessment is discussed in greater details below.

***The Knowledge and the Know-How***
*to count on a sufficient number of qualified workers and staff*

As stations age, the relative importance of maintenance increases, and the difficulty to perform maintenance tasks becomes increasingly complex, as one has to deal with intensifying radiation fields, for example. Hence, the necessity to be able to rely on a sufficient number of technically trained workers and qualified supervisory personnel. It is not easy either to attract personnel to older plants or to keep them there.

Some of the technology will become obsolete. To maintain or replace technical obsolescence adds on to the growing complexity of stations, and of operating and maintenance procedures, and it exerts increasing pressures on technical training programs intended for various categories of personnel: operators, trades, technicians and engineers. Often, those responsible for providing the training are themselves hardly equal to the task.

As for the safety aspect, the aim of the first phase of the PLM in the know-how area, after the finding of the first obviousness, is to bring out the main roads of future actions.

***The PLM Objectives***

The objectives of our PLM are (figure-5):

a) To maintain the long-term reliability and safety of Gentilly 2 during the nominal design life of 30 years (life assurance);

b) To maintain the long-term availability and capacity factors of Gentilly 2 with controlled and reasonable generating costs during the nominal design life of 30 years (life assurance);

c) To preserve the option of extending the life of Gentilly 2, with good safety and availability at reasonable costs, beyond the nominal design life of 30 years, up to 50 years or more (life extension).

## 4. The Hydro-Québec Approach

*the single reactor utility strategy: to team up and to go step by step*

Even though the Gentilly 2 station is only eleven years old, it is necessary to undertake a life assessment now and to initiate in-depth thinking about plant life management, to evaluate the impact on station life of decisions taken today on operation methods as well as on maintenance.

It is equally important to maintain the site licensed as a nuclear site for an operating reactor and to keep the nuclear option opened, just in case ...

It is highly desirable that any decision to decommission or extend the life of the station be taken on the basis of sound technical and economical data. To do so, a good way to proceed is to go step by step and to have key decision points as illustrated in figure-6.

Each significant advance in the program will lead to a decision by management to go further or to step back. In the same manner, a decision is required before any significant commitment is made in the refurbishment project.

In any of the three PLM options mentioned earlier, we have to work on the important and critical SSCs' long term maintenance strategy and programs. We have seen that there are strong incentives to further study the PLM fearures. On the other hand, technical assessment of the SSC's can be very expensive. Even though technical life assessment is station dependent, there are so many similarities between CANDU-6's that we have every reason to look for partnership in this area.

This is why we have been looking for partnership with New Brunswick Power (N.B. Power), who operates the Point Lepreau station, and with Atomic Energy of Canada Limited (AECL), the nuclear designer of the CANDU-6 reactor.

There are also other good reasons to get into a teaming agreement:

- N.B. Power has to answer to the same AECB generic action item about "Assurance of Continuing Nuclear Plant Safety";
- there is a need to provide the information with respect to available remaining life of major components necessary to support the evaluation of the merit of performing a reactor retub;
- this is an opportunity to spend smarter dollars in maintenance and in R&D;

- to have a credible scenario that the stations can run for more than 30 years. This could eventually be used in the marketing of CANDU internationally;

- to pool our scarce resources (manpower and dollars);

- to pool our experience in station design and operation;

- to add to the credibility of the assessment for:
  . the regulator
  . the senior management of our companies
  . the existing and potential customers.

The mission statement of our joint team for the assessment part of the PLM for CANDU-6 will be: "To perform the assessment phase of a program to manage the effects of ageing degradation to ensure continuing safe, reliable and cost effective operation of our existing CANDU-6 stations."

## 5. The Partnership Agreement

*every partner represents 1/3 of the team*

### ***Scope of the Agreement***

This three-party agreement (Hydro-Québec, N.B. Power and AECL) provides for the performance of phase one of the Plant Life Management program i.e. the Plant Life Assessment of Gentilly 2 and Point Lepreau, including the CANDU-6 generic issues.

### ***Terms of Reference***

*rules for a healthy cooperation*

The teaming agreement encompasses the following terms of reference, among others:

- to work by consensus of the three parties;

- every partner will share 1/3 of the total cost of the studies and will assume its share of the management of the agreement;

- to not reinvent the wheel, and to keep the costs of the studies as low as possible. For example:

  . use the best methodology of similar initiatives, such as the OECD NEA PLIM Group or the IAEA,
  . the EPRI terminology will be used, and
  . already available Canadian studies will be used as the basic technical reference documents.

The agreement and the studies will be managed by a Steering Committee composed of one representative from each partner.

Guidance of the technical activities will be done in consultation with a Technical Review Committee. It will be composed of up to two representatives named by each partner, in addition to the members of the Steering Committee.

For each study resulting in a Topical Report (the deliverable), there will be a Study Leader. Based on Ontario Hydro experience, we concluded that there are several advantages to locating the PLM study team leaders in a single location, the main one being the frequent exchanges that take place between them. Also, the Study Leaders should have early strong interface and relationship with the operations staff.

### ***Deliverables and Milestones***
*topical reports and a four-year schedule*

Figure-7 shows a summary of our master schedule for the assessment phase of the PLM program. The project is expected to last four years and it starts with two pilot studies. These pilot studies will be reviewed by the utilities management before going ahead with the three-year full scale project.

At the same time, a screening methodology and criteria will be developed and applied to the station safety related SSC's and to any non-safety related important SSC to draw up the list of the critical SSC's that will be subject to a topical study under this project. Topical studies preliminary list, in figure-8, will have to be substantiated.

The deliverables will be Topical reports. Figure-9 presents a typical report content. The recommendations for future actions should be worked out and should include cost estimates and a rough schedule.

### ***The Definition of the Critical SSC's***
*the trickiest part of the assessment phase*

There is no simple single list of equipment defined as critical SSC's because SSC's differ from plant to plant, and operating histories and physical environments further compound differences among plants.

Critical SSC's may be defined as the ones for which the difficulties, the cost and the plant shutdown time for refurbishment or replacement cannot be included in the normal maintenance program.

Criteria for the screening methodology used to assess the station SSC's in terms of ageing mechanisms may include elements such as:

- high impact on costs
- high impact on safety
- high impact on reliability
- high impact on plant availability.

The high impact on costs could include elements such as a prohibitive overall lifetime maintenance cost, replacement or repair technically extremely difficult, very high cost in terms of personnel radiation doses, or a prohibitive station outage time.

One positive approach could be to start with all safety-related SSC's, and not to focus on a few to start with. Then, if one has made a careful choice in his screening criteria, most of the components should fall under the existing programs, such as the maintenance, inspection, surveillance and testing programs. Only those SSC's not sufficiently covered by the existing programs or revised existing programs, generally not focusing on long term ageing issues, would be the subject of PLM assessment. These SSC's are the ones that we want to study in our PLM assessment phase.

The selection of adequate screening criteria is probably the thrickiest part of such an assessment phase. "If one sets these criteria too low, then too many components will require a full-blown analysis of ageing mechanisms, and program costs will skyrocket. On the other hand, if one sets the criteria too high, most of the components will undergo only a qualitative ageing analysis."

## CONCLUSION

There are, indeed, many obstacles on the road to life extension. Knowledge and know-how have to be maintained over the entire period. Annual O & M costs as well as refurbishment costs have to be controlled. Technical issues have to be mastered, such as the adequate definition of critical SSC's, the proper identification of degradation mechanisms and their effects on various components, and the sound assessment of remaining service life.

Even if human, budget and technical challenges are met, the life extension of a given station has to fit within utility planning, according to electrical demand and other energy options. For example, despite the same technical evaluation, N.B. Power and Hydro-Québec may eventually reach opposite decisions as far as the service life of our CANDU-6 stations.

A few years ago, there was real excitement world-wide about plant life extension and everybody in the US, for example, was talking about a twenty-year license renewal. We now see work done to apply on a more generic design basis through the Owners Groups. Also, utilities may not be ready to commit huge amounts of money for the long run and some are considering shorter terms, like five years. Ultimately, the regulator's requirements may have life-and-death consequences for nuclear stations.

## ACKNOWLEDGEMENTS

I wish to thank Mr. A. L. DeLong from N.B. Power and Mr. J. I. Saroudis from AECL.

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## BIOGRAPHY

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Mr. Ross holds a diploma in Physics Engineering and is a graduate in Nuclear Engineering from the Nuclear Engineering Institute of Montreal Polytechnic. He has great experience of commissioning and operating CANDU plants. As a reactor physicist, he actively participated in the Gentilly 1 NGS commissioning. He became manager of the Technical Division of Gentilly 1, and, subsequently, Chief Engineer responsible for mothballing the plant. He then was put in charge of commissioning the newly built Gentilly 2 NGS as Senior Commissioning Engineer. He directed the Operations and Planning Division of Gentilly 2 over its first years of operation.

**AECB GENERIC ACTION ITEM NO 90-G-03**
**ASSURANCE OF CONTINUING NUCLEAR STATION SAFETY**

... that physical **changes** occurring ... with the passage of **time**, are not compromising **safety** ...

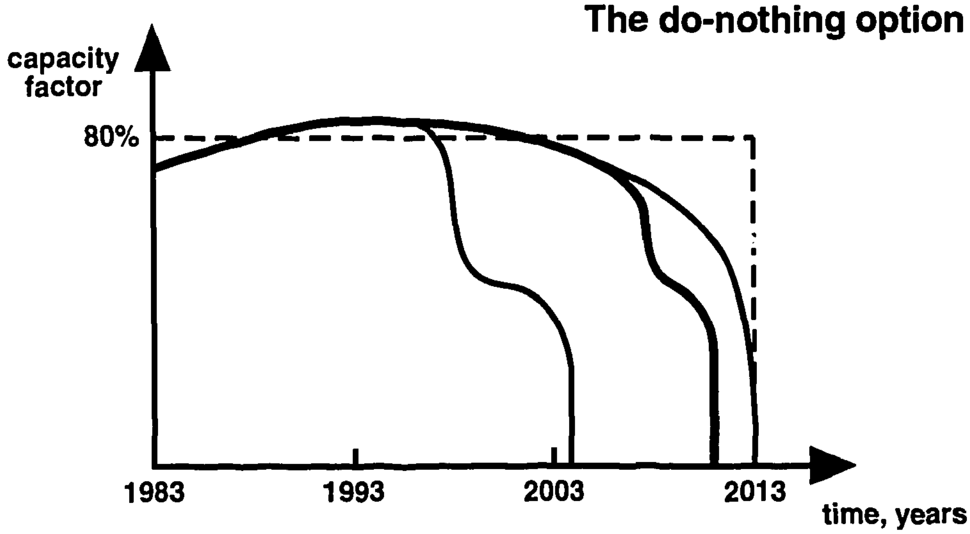
... potentially detrimental changes are being systematically identified and dealt with before they challenge the defense-in-depth design philosophy ...

You are **requested** to submit a summary of the means by which you remain **assured** of the **future safety** of your respective nuclear plants, **as they age.**

Figure 1

Gentilly 2 - PLM

**The do-nothing option**

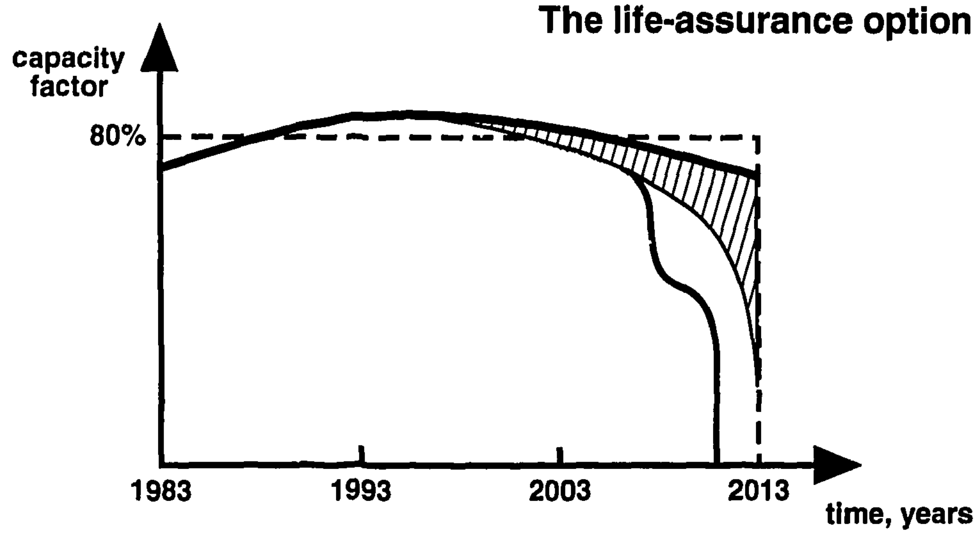



**Gentilly 2 lifetime projection of capacity factor**

Figure 2

## Gentilly 2 - PLM

The life-assurance option

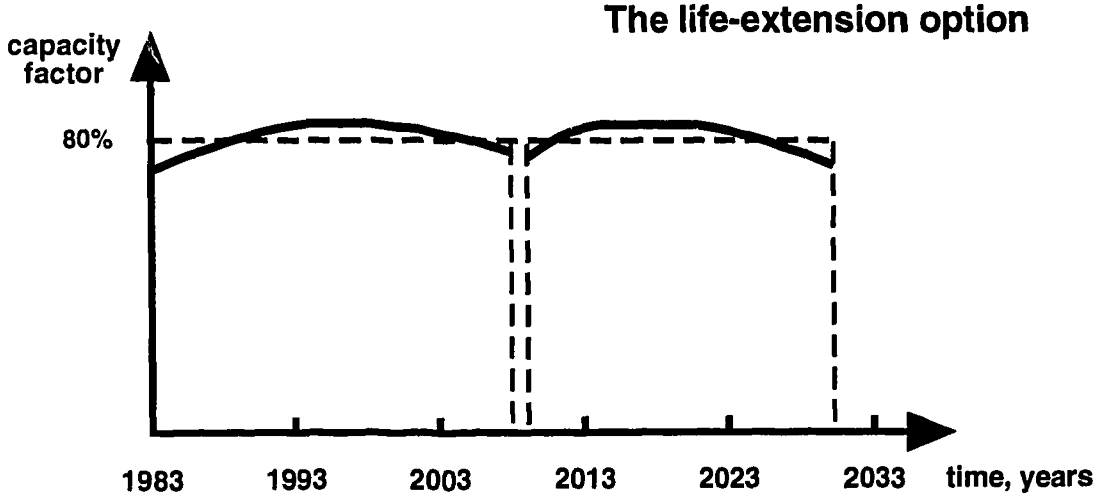



Gentilly 2 lifetime projection of capacity factor

**Figure 3**

## Gentilly 2 - PLM

The life-extension option




Gentilly 2 lifetime projection of capacity factor

**Figure 4**

## Gentilly 2 - PLM

### OBJECTIVES OF OUR PLM

**a)** To maintain the long-term reliability and safety of Gentilly 2 and Point Lepreau during the nominal design life of 30 years (life **assurance**).

**b)** To maintain the long-term availability and capacity factors of Gentilly 2 and Point Lepreau with controlled and reasonable generating costs during the nominal design life of 30 years (life **assurance**).

**c)** To preserve the option of extending the life of Gentilly 2 and Point Lepreau with a good safety and availability at reasonable costs, beyond the nominal design life of 30 years, up to 50 years or more (life **extension**).

Figure 5

## Gentilly 2 - PLM

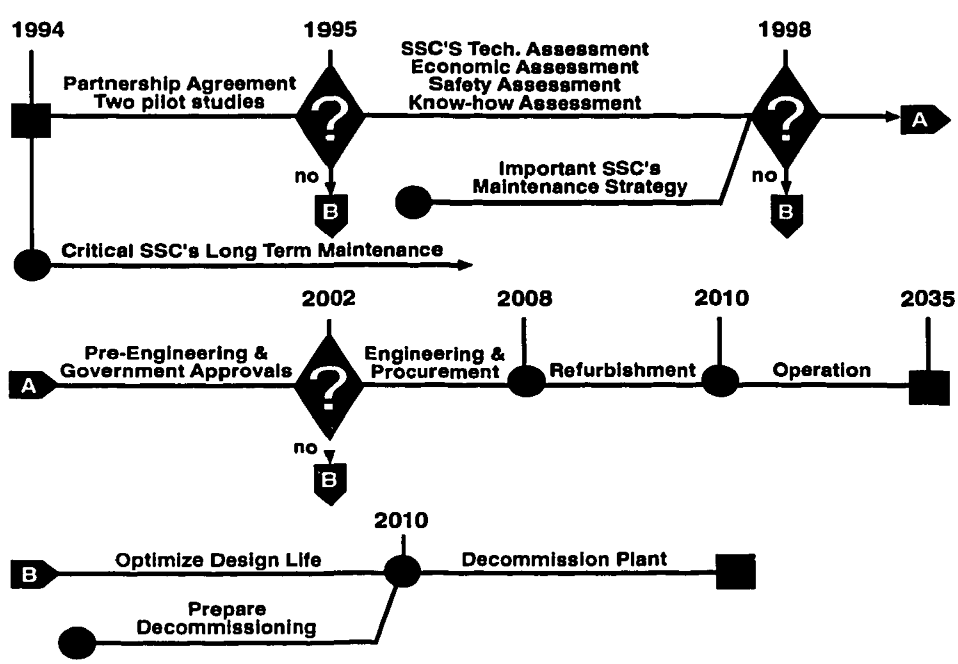



Figure 6

## Gentilly 2 - PLM

### CANDU-6 Assessment Phase Work Plan

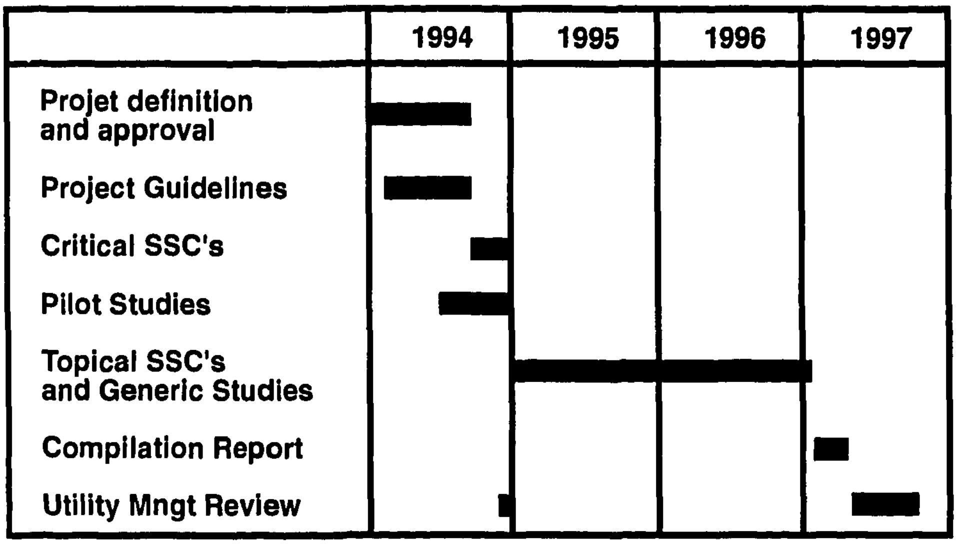



Figure 7

## Gentilly 2 - PLM

### CANDU-6 ASSESSMENT PHASE TOPICAL STUDIES PRELIMINARY LIST

- Reactor pressure tubes
- Steam generators
- Containment
- Reactor assembly and structures
- Civil structures
- Nuclear piping
- Conventional piping
- Instrumentation and control
- Cables
- Polar crane
- Transient and fatigue monitoring
- Safety at the current level
- Retub costs

Figure 8

## CANDU-6 ASSESSMENT PHASE TYPICAL TOPICAL REPORT CONTENT

Summary
1. Introduction
2. Description of the SSC and their sub-components
3. Design data
   3.1 Situations taken into account
   3.2 Functional criteria
   3.3 Working life indicator
   3.4 Safety requirements
4. Manufacturing and installation data
   4.1 Peculiarities or anomalies
   4.2 Methods of repair and replacement
5. Operational feedback
   5.1 Monitoring, inpection, testing
   5.2 Maintenance
   5.3 Canadian and international
6. Degradation mechanisms and life assessment
7. Data collection and record keeping
8. Recommendation for future actions
9. Conclusion

References

Figure 9