ABSTRACT:

Effective in-service surveillance of key safety-related structures, systems, and components (SSC) is an essential aspect for ensuring the long-term safety and reliability of nuclear power plants (NPP). This paper presents the Canadian Nuclear Safety Commission’s (CNSC) approach towards ensuring that licensees operate and maintain their NPPs in a safe condition. It describes the processes and requirements in place that ensure prompt notification is given to the regulator following the discovery of previously unconsidered ageing phenomena through in-service and periodic inspections or through in-service failures. The paper goes on to describe the regulatory response towards these events, which involves requiring the licensee to investigate the cause of the failure, re-assess the safety of the facility, adjust the controls on plant operation and surveillance, and implement measures to monitor the condition of the SSC. The paper also briefly discusses the known degradation mechanisms of key CANDU SSCs including dimensional and material changes of CANDU fuel channels, delayed hydride cracking of CANDU zirconium alloy pressure tubes, wall thinning and cracking of carbon steel feeder piping, degradation of CANDU steam generators, and degradation of CANDU containment systems and structures, and describes the requirements in place to ensure licensees sufficiently monitor the condition of these SSCs and appropriately disposition the results of these inspections. Finally, the paper describes the current and planned initiatives to improve the Canadian regulatory requirements and oversight for the surveillance of critical NPP SSCs and discusses the need to increase these efforts in order to account for the increasing effects of degradation mechanisms as Canada’s power reactors approach their end of design life.
INTRODUCTION

CANDU NPPs have been supplying electricity to the Ontario power grid since 1962 and to New Brunswick and Quebec power grids since 1983. At present, there are 20 CANDU units in Ontario, and one unit each in New Brunswick and Quebec. Currently two units in Ontario are in a defuelled state and three are in long-term guaranteed shutdown state – these units may be returned to service after comprehensive upgrading and refurbishment.

Canadian CANDU NPPs had excellent reliability in their early years of operation; however, as various effects of ageing began to accumulate, outages to address safety concerns resulted in a reduction of the availability of some plants. Ensuring the safety and reliability of ageing NPPs has thus become one of the more important tasks facing both the nuclear industry and the CNSC.

This paper deals with ageing management of Canadian CANDU NPPs from the regulatory perspective. The paper also reviews main safety related ageing concerns and mitigation strategies for key SSCs. It then describes Canadian regulatory approach to ageing management and licensees’ ageing management programs. Finally, the paper indicates a path forward involving a proactive ageing management approach.
1. CANADIAN REGULATORY APPROACH TO AGEING MANAGEMENT

In Canada, the CNSC has been the driver for dealing with many of the ageing concerns discussed below. In response to early signs of NPP ageing, CNSC staff implemented a “regulation-by-feedback” process (Fig.1). This process ensured that when component degradation was discovered, either through inspection results or component in-service failures, licensees investigated the degradation, assessed its safety impact, and adjusted controls to mitigate further degradation. Subsequent inspections verified the adequacy of the mitigating measures. This process was applied on a case-by-case basis, as new degradation mechanisms were identified.

In general, new forms of material degradation have been discovered through in-service inspections, and occasionally through in-service failures, such as pressure tube delayed-hydride cracking (DHC) or feeder stress-corrosion cracking (SCC). Through operating licences, the CNSC requires licensees to comply with in-service inspection standards, which provide extensive inspection requirements for nuclear safety related systems. In-service inspections have served to identify, at an early stage, degradation of safety-critical SSCs. Cracking on the extrados of feeder piping, discussed in section 4, is one such degradation mechanism that was identified through in-service inspections.

Recently, staff identified the need to further augment inspection requirements for high-energy non-nuclear safety important systems. Failure of these systems would not have significant radiological consequences, and therefore had not been included in nuclear in-service inspection standard; however these systems have the potential to affect conventional worker health & safety. CNSC staff are now evaluating the available means to incorporate additional inspection requirements in order to ensure that licensees are effectively monitoring the condition of high-energy conventional SSCs.

Through NPP operating licences, licensees are required to comply with Regulatory Standard S-99¹, which describes extensive reporting requirements for events at NPPs. In addition, through requirements for in-service inspections, licensees must report all in-service inspection indications that
do not meet defined acceptance criteria. These reports allow the CNSC to remain abreast of the overall plant condition at our licensees’ sites.

Having identified a previously unknown material degradation, staff require licensees to investigate extensively the cause of the failure, and to assess the implications of this failure on overall plant safety and on the existing safety case. Similar systems, which may be subject to this form of degradation, must also be inspected. Both staff and licensees use the information from these investigations to make a risk-informed decision whether to continue operation of the plant. This information is also shared with other operators to ensure that they also remain abreast of recent developments in reactor ageing.

Licensees are required to examine and implement measures to reduce the likelihood of further failures. In general, these measures may include increased surveillance, operating constraints such as reduced channel power limits, research projects and mitigating measures such as chemistry control. The approval to restart is granted only when the CNSC staff are satisfied that the licensee has a clear understanding of the causes of the degradation and that appropriate measures to mitigate further failures have been implemented.

Taking into account the information gained from the studies described above, rejection criteria for future inspection indications are also developed. These criteria are specified in Fitness-for-Service-Guidelines (FFSG). FFSGs include the maximum indication size for flaws based on the predicted inspection interval. This maximum size is based on the predicted growth rate of the flaw and ensures that the flaw will not propagate to failure prior to its next inspection.

The knowledge gained through these studies is used in the development of ageing models and modeling methodologies to predict component lifetimes. The operating histories of failed components also aided in determining the projected service life of similar components. As new failures occurred, it was recognized that a more preventive approach towards component ageing was also needed.

The CNSC has not issued explicit regulatory requirements on ageing management. However, a number of age-related regulatory requirements are included in the following regulatory documents: Class I Nuclear Facilities Regulations^2 (requiring licensees to describe “the proposed measures, policies, methods and procedures for operating and maintaining the nuclear facility”); R-7, Requirements for Containment Systems for CANDU Nuclear Power Plants^3, R-8, Requirements for Shutdown Systems for CANDU Nuclear Power Plants^4, and R-9, Requirements for Emergency Core Cooling Systems for CANDU Nuclear Power Plants^5 (requiring that safety systems are available to operate when called upon); regulatory standard S-98, Reliability Programs for Nuclear Power Plants^6 (requiring development of system availability limits and minimum functional requirements, and description of the inspection, monitoring, and testing activities designed to ensure system availability); specific conditions of an NPP operating license.

In order to address ageing, the licensees are required to inspect and perform material surveillance according to the technical requirements of CSA standards N285.4^7 (Periodic inspection of CANDU nuclear power plant components), N285.5^8 (Periodic inspection of CANDU nuclear power plant containment components), and N287.7^9 (In-service examination and testing requirements for concrete containment structures for CANDU nuclear power plants). These requirements include inspection techniques, procedures, frequency of inspection, evaluation of inspection results, disposition, and repair.
Maintenance programs are required for the purpose of limiting the risks related to the failure or unavailability of any significant SSC. For so-called “destiny components” (pressure tubes, feeder piping, and steam generator tubes), in addition to the standards’ minimum requirements, the CNSC requires NPP licensees to develop fitness-for-service guidelines and life cycle management plans/programs.

2. LICENSEES’ AGEING MANAGEMENT PROGRAMS

By the end of the 1980’s licensees had programs in place related to ageing, however they had not yet adequately integrated them into a comprehensive and systematic ageing management strategy. As a result, in 1990, CNSC Staff requested licensees to demonstrate that:

- potentially detrimental changes in the plant condition are being identified and dealt with before challenging the defense-in-depth philosophy;
- ageing related programs are being effectively integrated to result in a disciplined overall review of safety;
- steady state and dynamic analyses are, and will remain, valid;
- a review of component degradation mechanisms is being conducted;
- reliability assessments remain valid in light of operating experience; and
- planned maintenance programs are adequate to ensure the safe operation of the plant.

CNSC staff recommended that the licensees use the International Atomic Energy Agency (IAEA) guideline “Implementation and Review of a Nuclear Power Plant Ageing Management Programme” as an appropriate framework for such a program. As a result of the above request, the Canadian nuclear industry put systematic ageing management programs in place that were based on the IAEA guidelines. The specific processes and procedures developed in support for the ageing management plant varied from licensee to licensee, though a summary of the general approach is presented below.

Using the guidance provided by the IAEA documents, licensees undertook efforts to identify gaps in their operating policies and procedures with regards to the ageing management of critical components. Initially the licensees focused on the selection of critical components. Most licensees decided to incorporate economically “critical” components as well as the safety critical ones into an overall plant life management program, the remaining focused only on those components critical to safety. The CNSC supports either approach provided the safety critical components are sufficiently addressed.

Programs were developed that considered the known degradation mechanisms of the selected components. Licensees also considered operating experience to ensure that all mechanisms that had previously caused failures were addressed. The programs already in place to deal with known degradation mechanisms were evaluated to determine their effectiveness.

Coincident with the above activities, licensees developed, on their own or in conjunction with the plant designer, generic procedures for evaluating component and system ageing. Along with these, condition assessments of the major plant components were and are being performed. These assessments evaluated the feasibility, from a safety standpoint, of continued use of the components.

CNSC staff recognize that the current level of licensees’ ageing management effort may need to be further augmented in order to ensure plant safety as Canadian NPPs continue to age. This will require strengthening the role of proactive ageing management utilizing a systematic ageing management process. Section 5 describes some initiatives that the CNSC is undertaking to address this concern.
### 3. AGEING CONCERNS IN CANDU NUCLEAR POWER PLANTS

This section presents in Table I an SSC-oriented summary of main ageing concerns that challenge CANDU plant safety as it ages; some of these concerns are unique to CANDU and some are applicable to nuclear plants in general.

<table>
<thead>
<tr>
<th>Component</th>
<th>Degradation Mechanisms &amp; Effects</th>
<th>Safety Concern</th>
<th>Regulatory Requirements</th>
<th>Mitigation Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure tube (PT)</td>
<td>Irradiation-enhanced deformation of PT (sag, axial creep, diametral creep &amp; wall thinning), DHC, material property changes</td>
<td>Failure of PT, (small LOCA), inadequate fuel cooling</td>
<td>N285.4-95 FFSGs, Life cycle mgmt plan</td>
<td>Design/material/manufacturing improvements (replacement PTs), chemistry control, improved leak detection, trip set-point reductions, inspection</td>
</tr>
<tr>
<td>Calandria tube (CT)</td>
<td>Irradiation-enhanced deformation of CT: sag</td>
<td>Impairment of SDS 2 (LISS nozzles)</td>
<td>PROL License Condition 3.5 CSA N285.4</td>
<td>Monitor CT-nozzle interference, reposition nozzle, replace FC</td>
</tr>
<tr>
<td>Feeder pipe</td>
<td>Wall thinning due to Flow Accelerated Corrosion, Stress Corrosion Cracking, H-assisted low-T creep cracking</td>
<td>Failure of feeder pipes (small LOCA), primary coolant leakage</td>
<td>CSA N285.4 FFSGs, Life cycle mgmt plan</td>
<td>Chemistry control, addition of chemical inhibitors, repair/replace, inspection</td>
</tr>
<tr>
<td>Steam generator tubes and heat exchangers</td>
<td>Corrosion (SCC, IGA, pitting, wastage), fretting, denting, erosion, fouling</td>
<td>Tube leaking or rupture, possible releases</td>
<td>CSA N285.4 OP&amp;P Limits, FFSGs, Life cycle mgmt plan</td>
<td>Inspection and tube plugging. Chemistry control, water-lancing and secondary side chemical cleaning, installing additional bar supports to reduce vibration</td>
</tr>
<tr>
<td>HTS</td>
<td>Surface roughening and fouling due to magnetite deposition</td>
<td>Increased reactor inlet temperature, flow redistribution</td>
<td>R-8, ROP/NOP trip setpoint reduction</td>
<td>Primary side cleaning, alternative flow measurements, condition monitoring</td>
</tr>
<tr>
<td>PVC cable</td>
<td>Radiation and temperature-induced embrittlement</td>
<td>Insulation failure leading to current leaks and short circuits</td>
<td>R-7, R-8, R-9, L.C. 7.1</td>
<td>Develop effective EO programs, procedural controls, test plans, visual inspection</td>
</tr>
<tr>
<td>Containment structure</td>
<td>Thermal cycling, periodic pressurizing, fabricating defects, stress relaxation, corrosion, embrittlement</td>
<td>Loss of leak tightness, structural integrity leading to possible releases</td>
<td>CSA N287 series, CSA N285.5, R-7</td>
<td>Pressure testing, visual inspections, concrete coating</td>
</tr>
<tr>
<td>Reactor assembly</td>
<td>Corrosion (SCC), erosion, fatigue, creep, embrittlement</td>
<td>Loss of moderator containment, shielding</td>
<td>CSA N285.4</td>
<td>Visual inspection, leak monitoring, lifetime predictions</td>
</tr>
</tbody>
</table>

**TABLE I: Summary of Ageing Concerns in CANDU Power Plants**
A distinct feature of the CANDU reactor is that heat generation occurs in 380-480 horizontal Zr-Nb pressure tubes (PTs), rather than a large pressure vessel (Fig.2). There are three significant pressure tube degradation mechanisms: irradiation-enhanced deformation (axial creep, sag, radial creep and wall thinning), delayed hydride cracking and irradiation-induced changes in PT material properties. Operating experience and ongoing R&D have enhanced substantially their understanding and predictability.\textsuperscript{12-16} Related safety concerns include the following potential problems: CT contact with reactivity mechanisms and associated impairment of their function; PT rupture and associated impairment of fuel cooling; reduced margins to demonstrate LBB and increased risk of PT rupture.

The cornerstone of the strategy for mitigating degradation of PTs is monitoring and characterization which is mandatory under Power Reactor Operating Licenses. CSA Standard N285.4-94\textsuperscript{7} establishes minimum requirements for PT inspections, including the scope and schedule for various inspections (inaugural, periodic and material surveillance), as well as acceptance criteria for inspection findings (or “indications”); it defines specific inspections to detect and characterize indications resulting from each of the above PT degradation mechanisms. Should there be an indication that does not meet the acceptance criteria, the licensee is obliged to follow CNSC-approved “fitness-for-service guidelines” (FFSG) to demonstrate that the PT remains fit for continued service; there are three possible courses of action: returning the tube to service (usually with certain restrictions); repairing the indication; or replacing the PT.

Current pressure tube FFSGs allow for the use of probabilistic methods for PT condition monitoring, operational assessments, and inspections. In order to make use of these methods, licensees must demonstrate that all existing regulatory requirements are met, that the principles of defense-in-depth are maintained, that sufficient safety margins are ensured, and that the proposed increase in risk and cumulative effects are small and do not exceed CNSC safety goals. The current uses of these tools include: risk-informed inspection scoping (inspection size and frequency determination), statistically based estimation of parameters for fitness assessments (i.e. a percentile of a cumulated distribution of measured properties), and as an alternative for DHC and hydride blister predictions (although this option has not yet been explored).

In addition, licensees have recently proposed an update to the existing PT FFSGs. A part of these FFSGs include a requirement for a core assessment, for which the CNSC has been a driver. Under this requirement, licensees are required to assess the cumulative effects of PT degradation mechanisms on the integrity of pressure tubes throughout the entire core. This involves:

- evaluating the adequacy of material fracture toughness;
• evaluating the identified degradation mechanisms for the balance of pressure tubes that were not inspected;
• assessing leak-before-cracking in cases where the hydrogen equivalent concentration is greater than the terminal solid solubility for hydrogen dissolution (TSSD) at sustained hot condition; and,
• assessing the change of PT properties from surveillance information, including hydrogen equivalent concentration, fracture toughness, DHC growth rate, and threshold intensity factor for onset of DHC from a crack.

Probabilistic methods for these evaluations, i.e. analysis methods that determine the distributed output of engineering analyses based on probabilistic representations of distributed input parameters, are an important and powerful tool. Prior to making full use of these tools, however, CNSC staff foresee the need for further refining these methods, including the completion and/or further verification of probabilistic representations of distributed input parameters, and further justification of the proposed probability acceptance levels for the results of a probabilistic analysis.

Feeder piping, made from seamless cold drawn carbon steel, is used to supply fuel coolant to individual pressure tubes (Fig.3). There are two significant ageing mechanisms of feeder pipes: excessive wall thinning and cracking. Excessive wall thinning is due to Flow Accelerated Corrosion (FAC) and cracking is speculated to be caused by Stress Corrosion Cracking (SCC) and creep cracking. These mechanisms have been prominent in outlet feeders, which are subject to harsher operating conditions than inlet feeders. The mechanistic understanding of FAC wall thinning is commonly taken to mean corrosion caused by the flow accelerated dissolution of magnetite (Fe₃O₄) on the inside surface of the outlet feeder pipe.¹⁷ The rate of feeder pipe wall thinning depends on water chemistry, particularly the coolant pH and on flow characteristics such as velocity and turbulence. Axial cracking has been observed in outlet feeder pipes at both the inside surface and the outside surface of the feeder pipe bend downstream of the PT connection. One through-wall circumferential crack was also discovered at the inside surface at a repaired field weld on the feeder. All of the cracks in the feeder pipe show intergranular paths.

The understanding about the cracking mechanism is still in the speculation stage. The cracking initiated at the inside surface is believed to be Intergranular Stress Corrosion Cracking (IGSCC) due to an oxidizing water environment. High residual stresses in feeder bends (which vary from reactor to reactor due to different manufacturing techniques) accompanied by the chemical environment produces favourable conditions for this cracking. The most likely mechanism of the outside surface cracking is argued to be a low-temperature creep cracking enhanced by hydrogen. The related safety concern is a potential pressure boundary failure and leakage of reactor primary coolant, if FAC and cracking are allowed to progress unchecked.

The strategy for mitigating wall thinning of feeder pipes due to FAC consists of chemistry control (reduced pH) and corrosion inhibitors to reduce the rate of degradation, inspection and monitoring to detect cracking and wall thinning of feeders, and repair/replacement of feeder pipes when the wall thickness is below an acceptable limit. Following the discovery of FAC thinning, CNSC staff required licensees to develop improved techniques, methodology, and accuracy for feeder thickness measurements and thinning rate assessments; the CNSC has approved licensee developed Feeder Piping Life Cycle Management Plan and Fitness-for-Service Guidelines.
CNSC has also approved a methodology for determining the minimum required feeder thickness based on ASME Sections III and XI. CNSC reviews the inspection results and wall thinning assessments at each planned Outage and grants approval of reactor operation based on the predicted thickness of the feeder piping at the next planned inspection and the minimum required thickness. Pipe sections with confirmed cracks must be removed or replaced until an effective methodology to determine the acceptability of cracks in feeders is developed. For the stations where cracking has been discovered, CNSC has required the licensee to expand their inspection scope to cover all the high-risk sites such as tight radius bends and repaired field welds. CNSC has also requested the licensee to replace feeders which had been dispositioned due to wall thinning, to ensure sufficient safety margin in the event of a crack initiating and propagating at the thinned location of the feeder. CNSC has also asked licensees to improve non-destructive examination (NDE) for detecting feeder cracks which can be difficult to detect due to their characteristics such as a scalloped surface, secondary cracking, multiple surface cracks and discontinuities of cracks causing ultrasound reflections.

Licensees have made efforts to improve leak-detection systems, which provide early detection of leaking cracks. In addition, R&D effort administered by CANDU Owner’s Group (COG) aims to develop more effective ageing management for feeder pipes. Recently COG performed a feasibility study of the application of probabilistic methods to feeder cracking. The feasibility study examined whether a probabilistic model for feeder cracking and feeder rupture can be developed, while ensuring that the frequency of feeder failure remains sufficiently low so as not to affect the reactor safety case. The study concluded that it is possible to develop such a model for estimating the probability of feeder cracking and to support life-cycle management decisions. CNSC staff feel that research to increase the level of mechanistic understanding is needed to reduce model uncertainty due to the limited understanding about feeder degradation mechanisms. COG has also begun research efforts to demonstrate that the feeder cracking failure mechanism would be leak-before-break (LBB). CNSC staff considers this effort to ensure the defence-in-depth safety concept rather than to disposition detected cracks.
**CANDU steam generators (SGs)** are similar in construction to PWR steam generators and suffer from similar ageing degradation mechanisms and effects, such as corrosion (SCC, IGA, pitting, wastage), fretting, denting, and erosion of SG tubes.\(^{18-19}\) Comparable regulatory controls and ageing management actions are being used in Canada, however to date, no SGs have been replaced. The SG FFSG, accepted in 1999, make use of probabilistic tools for performing LBB simulations for the determination of flaw stability within the entire tube population and for determining flaw size distributions for condition monitoring and operational assessments. The SG FFSG considers the probabilistic approach as an alternative to deterministic methods. Shortcomings of current probabilistic methods and SG FFSG include:

- the use of “pattern-based” variables, which do not make use of mechanistic or physics of degradation tools;
- the lack of a clear basis for probabilities and distribution parameters;
- the tools are primarily reactive, rather than proactive; and,
- FFSG does not address inspection scoping.

Most of the other ageing concerns of Table I are generic nuclear plant problems. For example, the use of PVC-insulated cables inside reactor buildings has been a major ageing concern for all NPPs, including CANDU reactors. Similar regulatory controls and ageing management actions are being used in Canada, including cable replacement in connection with NPP upgrading/refurbishment.\(^ {20}\)

### 4. PATH FORWARD

CNSC staff recognizes that the current level of ageing management effort may need to be increased to ensure plant safety as Canada’s NPPs continue to age. Due to the fact that the Canadian regulatory process to address ageing evolved on a case-by-case basis, the current regulatory approach is reactive rather than proactive, and lacks consistency by focussing on individual cases. CNSC staff are implementing measures to strengthen the role of proactive ageing management by focusing on important SSCs susceptible to ageing degradation and greater application of the systematic ageing management process utilizing Deming’s Plan-Do-Check-Act cycle.\(^ {10}\)

Proactive ageing management means being in control of SSC ageing while, in contrast, reactive ageing management means using a run-to-failure strategy. Proactive ageing management also involves providing for adequate understanding and predictability of SSC ageing, minimizing premature ageing (that is caused by errors in design, installation, operation, maintenance, inadequate communication between design, technical support, operations and maintenance functions, and unforeseen ageing phenomena), adjusting the use of proactive and reactive ageing management strategies based on existing understanding and predictability of SSC ageing, and continuous improvement of SSC specific ageing management programs.

To strengthen the role of proactive ageing management at Canadian NPPs, CNSC will continue maintaining and improving regulatory documents, standards and compliance program activities, and encourage further research on ageing degradation of SSCs important to safety, as needed.

Currently, effective regulatory oversight of licensees’ ageing management programs is hampered by the lack of explicit regulatory requirements on ageing management. Without common benchmarks it is difficult to ensure consistency and uniformity of compliance assessments of ageing management programs at different licensee sites. As a result, CNSC staff have undertaken the production of a
The objectives of this regulatory standard are to:

- describe the organizational characteristics of an effective ageing management program;
- describe the general attributes of an effective ageing management program for managing specific ageing mechanisms and their effects on particular SSCs or types of SSCs;
- inform NPP licensees of CNSC expectations and recommendations relating to ageing management of SSCs important to safety; and to,
- facilitate CNSC evaluations of the effectiveness of NPP ageing management programs within the framework of CNSC’s compliance program.

CNSC staff are planning for the regulatory standard to include, as part of licensees’ overall ageing management programs, such requirements as:

- Plant Reviews: involving a systematic review of the plant to identify all the SSCs which must be addressed by the program and the potentially detrimental effects of ageing on the ability of each of the SSCs to meet their design requirements;
- Gap Analyses: involving an assessment of the adequacy and effectiveness of existing activities already in place to manage each SSC’s ageing, and to identify enhancements or additions to these activities; and,
- Documentation: including the governing ageing management programs procedures and the requirements for continuous improvement of the program, as well as the procedures for all supporting programs and activities.

The regulatory standard is intended for both CNSC staff and NPP licensees: NPP licensees will use the document as a benchmark for self-assessments of their ageing management programs, and CNSC staff will use the document as a regulatory basis for ongoing compliance inspection of ageing management programs and for comprehensive licensing assessments of licensee long-term operation applications. CNSC staff expect that this standard will result in an increased effectiveness of licensee ageing management programs and an increased reliability of SSCs important to safety, thus improving NPP safety.

The CNSC also foresees the need to further develop and improve probabilistic tools for condition assessments and condition monitoring of critical SSCs. Some specific uses of these tools are described in section 4, and will result in a more risk-informed approach towards managing the ageing of Canadian NPPs. In addition, the CNSC is moving towards the use of process-based approvals (PBA) for dispositions of certain well-understood ageing phenomena. PBAs will allow licensees to self-disposition low-risk inspection indications provided the disposition is performed in accordance with accepted FFSGs and with an approved and regularly audited procedure. CNSC staff foresee that an increased use of PBAs will result in improved regulatory effectiveness and efficiency, while reinforcing the CNSC’s policy that licensees bear primary responsibility for ensuring the safe operation of NPPs.
5. REFERENCES

20. CNSC INFODOC-0385: “Aging Behaviour of Electrical Cables”