Canadian Regulatory Approach to Ensuring the Implementation of Effective Ageing Management Programs for Nuclear Power Plants

Andrei Blahoianu, Thomas Viglasky, Colin D. Moses and Ken Kirkhope
Canadian Nuclear Safety Commission, Ottawa, ON

ABSTRACT

Effective ageing management is a key element of the strategy for maintaining long term safety and reliability of nuclear power plants (NPPs). This paper presents the Canadian regulatory perspective on managing the ageing of CANDU NPPs. This paper looks introspectively at the current level of ageing management effort at Canadian reactor sites, and discusses the need to increase efforts in order to account for the increasing effects of degradation mechanisms. It examines accepted international practice for ageing management, making reference to International Atomic Energy Agency (IAEA) suggested practice, and goes on to describe the overall Canadian regulatory approach to ageing management, including the development of regulatory requirements for ageing management programs. In conclusion, the paper indicates a path forward involving a proactive ageing management approach.

INTRODUCTION

CANDU NPPs have been supplying electricity to the Ontario power grid since 1962 and to the New Brunswick and Quebec power grids since 1983. At present, there are 20 CANDU reactor units in Ontario, and one unit each in New Brunswick and Quebec operating under licences issued by the Canadian Nuclear Safety Commission (CNSC). Table 1 summarizes the age distribution of these units and shows that most are fast approaching or past 20 years operation. The design life for current operating CANDU reactors is nominally 30-40 years, however the experience has been that the reactors require refurbishment after about 25 effective full power years to replace all of the pressure tubes, and possibly other major components such as feeders or steam generators, due to ageing related degradation. The unit in New Brunswick and two units in Ontario are undergoing refurbishment projects to extend their operating life a further 25 to 30 years. Other licensees are performing the safety reviews and evaluating the business cases for extended life or long term operation (LTO) of their plants. Refurbishment was determined to not be economically feasible for two units in Ontario and these are being placed in long-term safe storage state until decommissioning.

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 significant 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, particularly as NPPs are considering extended long-term operation. Experience has shown that a proactive approach to ageing management is required through the life-cycle of a NPP, beginning early in the design phase for new builds, and continuing through construction and commissioning, operation and possibly extended long term operation, and finally through decommissioning.

This paper deals with ageing management of Canadian NPPs from the regulatory perspective. The paper describes the Canadian regulatory approach to ageing management, and licensees' ageing management programs, and indicates a path forward involving a proactive life-cycle approach to ageing management. A number of ageing-management and structural integrity initiatives with industry and other national regulatory agencies both, within Canada and at international level are described. On a final note, the paper describes the current and planned initiatives to improve the Canadian regulatory requirements for ageing management programs, as well as the oversight for the surveillance of critical systems, structures and components (SSCs), including the use of probabilistic methods for condition monitoring and operational assessment, and risk-informed in-service inspections.

REGULATORY APPROACH TO AGEING MANAGEMENT

Response to Ageing Degradation

The early high level of performance of CANDU NPPs resulted from solid design and construction, efficient operation by well trained and experienced staff and expert technical support. At the design phase, the known ageing mechanisms were considered and their predicted rates were accounted for to the best of the knowledge available at that time. Theoretically this would have allowed the plants to operate to their end of design life without the need to replace many long-lived components. However, new forms of material degradation have been discovered through in-service inspections, and occasionally through in-service failures, such as flow-assisted corrosion (FAC) of steam generator tube-support plates (TSP), 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. Licensees must report all in-service inspection indications that do not meet defined acceptance criteria. In addition, licensees are also required to comply with Regulatory Standard S-99 [1], which describes extensive reporting requirements for safety significant events and findings at NPPs. These reports allow the CNSC to remain abreast of the overall plant condition at our licensees' sites.

Having identified a previously unknown material degradation, licensees are required 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.

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 (FFSGs). 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 also 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.

This process ensures that when component degradation is discovered, either through inspection results or component in-service failures, licensees investigate the degradation, assess its safety impact, and adjust controls to mitigate further degradation. Subsequent inspections are used to verify the adequacy of the mitigating measures. This process is applied on a case-by-case basis, as new degradation mechanisms are identified. However, it is also recognized that a more preventive approach towards NPP ageing is needed.

Ageing Management Programs

The CNSC has been a long time proponent of early identification, proactive assessment and strategic safety management of ageing components and systems at NPPs. Ageing of safety critical structures, systems, and components (SSCs) was being addressed proactively through a number of programs, such as a 'durability program' for major SSCs initiated at NPD nuclear generating station in 1970's and the Nuclear Plant Life Assurance program of the Nuclear Generation Division of Ontario Hydro initiated in 1980's. 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 defence-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"[2] 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, a summary of the general approach is presented below.

Using the guidance provided by the IAEA documents [2], 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.

As is discussed in a later section of this paper, CNSC staff recognizes that the current level of ageing management effort may need to be further augmented to ensure plant safety as Canada's NPPs continue to age. CNSC staff are implementing measures to strengthen the role and consistency of implementation of proactive ageing management programs, including development of a Regulatory Standard to outline the regulatory expectations for NPP licensees' ageing management programs.

Ageing Management Reviews for Life Extension

As mentioned in the introduction, several Canadian NPP licensees are undertaking refurbishment projects to extend the life for LTO. In the coming years, it is expected that other Canadian NPPs will be evaluating the feasibility of life extension. The CNSC Draft Regulatory Guide G-360 [3] provides information on the key elements to be considered when a licensee undertakes a project to extend the life of a nuclear power plant. One of the major elements to assess the safety operation of the plant for the extended period is the Integrated Safety Review (ISR). The ISR is a comprehensive assessment of plant safety performed by the licensee in accordance with IAEA Safety Guide on Periodic Safety Review (PSR) of Nuclear Power Plants [4]. The main objectives of the ISR are to determine:

- the extent to which the plant conforms to modern standards and practices
- the extent to which the licensing basis will remain valid to the end of the proposed operating life
- the adequacy of the arrangements that are in place to maintain plant safety for long-term operation
- the improvements to be implemented to resolve the safety issues that have been identified

Life extension depends, among other things, on the material condition of the plant which is influenced significantly by how well ageing has been controlled or managed. The scope of the ISR includes a number of review areas (termed "Safety Factors") identified in G-360 [3] and the IAEA Safety Guide on PSR [4]. The Safety Factors on "Ageing Management", as well as "Plant Design", "Actual Condition of SSCs", and "Equipment Qualification" are all associated with plant material condition and ageing. The objective of the ISR Safety Factor on Ageing Management is to determine whether ageing in a nuclear power plant is being effectively managed so that required safety functions are maintained, and whether an effective ageing management program is in place for future plant operation. The specific review elements for the Safety Factor on Ageing Management include:

- Ageing Management Program policy, organization and resources.
- A documented method and criteria for identifying SSCs covered by the ageing management program.
- A list of SSCs covered by the ageing management program and records that provide information in support of the management of ageing.
- Evaluation and documentation of potential ageing degradation that may affect the safety functions of SSCs.
- The extent of understanding of dominant ageing mechanisms of SSCs.
- The availability of data for assessing ageing degradation, including baseline, operating and maintenance history.
- The effectiveness of operational and maintenance programs in managing ageing of replaceable components.
- The program for timely detection and mitigation of ageing mechanisms and/or ageing effects.
- Acceptance criteria and required safety margins for SSCs.
- Awareness of physical condition of SSCs, including actual safety margins, and any features that would limit service life.

In the framework of an ISR, the licensee therefore evaluates the effects of ageing on NPP safety, effectiveness of ageing management programs for future operation and the need for their improvements. This includes: reviews of time-limited aging analyses (analyses that are based on an explicitly assumed time of plant operation, e.g. for radiation-induced deformation and embrittlement, metal fatigue, thermal ageing, loss of material and equipment qualification); systematic identification of structures and components subject to life extension ageing reviews; condition assessment of these SSCs against defined acceptance criteria, and reviews of the effectiveness of SSC specific ageing management programs against defined attributes. These results of these ISR reviews should establish for each SSC subject to ageing review whether:

- All significant ageing mechanisms have been identified.
- There is a thorough understanding of the relevant ageing mechanisms and their effects.

- Ageing behaviour over the period of operation to date is consistent with predictions.
- There are adequate margins in respect of ageing to ensure safe operation for extended life / LTO or whether there are any life limiting issues.
- There are effective ageing management programs (including operational, chemistry, maintenance, surveillance and inspection) in place for future plant operation.

Possible outcomes of the ISR review of NPP ageing are improvements to maintenance programs, changes to surveillance and inspection scope, procedures and/or frequency, and modifications of operating conditions or design (including possible changes of the SSC design basis).

REGULATORY STANDARD ON AGEING MANAGEMENT

With most of the current Canadian NPPs fast approaching or past 20 years operation, and with long term operation planned for some plants, CNSC staff recognizes that the current level of ageing management effort may need to be further augmented to ensure plant safety as Canada's NPPs continue to age. Recent ageing management program reviews have indicated the current regulatory approach lacks consistency by focusing on individual cases. 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 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 [2]. This includes undertaking the production of Regulatory Standard S-334 which outlines the regulatory expectations for NPP licensees' ageing management programs. This standard will reflect the key ageing management approaches and emphasizes the adoption of a life-cycle approach to ageing management as well as the establishment of a systematic ageing management program.

Following review of the various international guidance and approaches to ageing management, certain key aspects of an effective ageing management approach have been identified for inclusion in S-334. The first emphasizes the need to give appropriate consideration to ageing at all stages in a facility's life cycle. When making decisions with respect to the design, fabrication, construction and commissioning, operation and decommissioning, due consideration to the effects of those decisions on the ageing degradation of a facility will serve to minimize the risk of unforeseen or higher-than-expected degradation rates. Secondly, the early adoption of a systematic ageing review process ensures that the actual ageing degradation of critical ageing SSCs as well as the assumptions made during design and program development are periodically reassessed. These two concepts are expanded in the following sections.

Life-Cycle Approach

A proactive strategy requires the implementation of ageing management activities throughout the lifecycle of NPPs and their SSCs. At the design stage, measures and features should be incorporated in order to facilitate the implementation of ageing management throughout the lifecycle of the plant. The design process should include a systematic process to identify all potential ageing degradation mechanisms, ensuring that the effects of ageing are being appropriately taken into account in the safety analysis and in specifications for the design, fabrication, commissioning, operation, inspection and maintenance of the SSC. This process should include reviewing recent relevant operating experience and research findings.

Safety margins included in the design of structures and components should take into account all relevant ageing and wear-out mechanisms as well as potential age-related degradation in all foreseen normal and abnormal operating conditions. Ageing and wear-out effects due to testing, maintenance and outages shall also be taken into account. In addition, the provisions for monitoring, testing, sampling and inspection to assess the progression of ageing mechanisms, to verify design predictions and to identify unanticipated behaviour or degradation that may occur during operation.

During fabrication and construction, the current ageing management knowledge and other relevant factors affecting ageing and ageing management should be taken into account. In particular, the effects of the chosen fabrication techniques on the eventual ageing of the structure or component should be considered. In addition, particularly where inspection of a component is difficult or dangerous, alternate provisions to monitor ageing degradation, such as the use of surveillance specimens, should be considered.

During operation, an ageing management program (AMP) is implemented to ensure the capability of the NPP to perform the necessary safety functions throughout its planned operating life, to assess ageing effects, and to identify unexpected behaviour or degradation during service. The AMP coordinates all programs and activities relating to the understanding, control, monitoring, and mitigation of ageing in existing programs such as NPP operations, engineering, chemistry control, configuration management, equipment qualification, testing and maintenance, SSC monitoring, periodic and in-service inspection, fitness-for-service assessments, component life-cycle and plant life management, and research and development. Wherever possible, preference should be given to procedures that minimize the likelihood of excess degradation, such as slow cool downs to minimize fatigue and thermal stresses. Ageing management activities should continue into decommissioning for all SSCs required to perform during the decommissioning phase.

Ageing Management Program Implementation

In order to successfully manage the AMP, appropriate organizational arrangements should be established. Initially, the policy and objectives of the AMP need to be developed, and sufficient resources allocated to develop and manage the program. Clear responsibility for the overall AMP, including the co-ordination of relevant supporting programs and the performance of periodic reviews of the AMP and continuous improvement activities, should also be assigned. The interfaces between the AMP unit and other organizational units should also be established, with responsibility for the implementation of SSC-specific recommendations clearly defined. Finally, provisions to monitor the program and ensure that it is meeting its objectives should be established.

Other supporting programs are also required. An effective data collection and record keeping system is essential to ensuring access to ageing-related information for safety-important SSCs. Such information includes design and design change documentation, operating history, maintenance history, inspection and surveillance results and operating experience. Provisions to verify the validity of information entered into the system are also necessary. The data collection and record keeping system may be used to provide information for ageing management activities such as:

- identification and evaluation of degradation, failures and malfunctions of SSCs caused by ageing effects;
- decisions on the type and timing of preventive maintenance actions, including repair, refurbishment and replacement;
- optimization of operating conditions and practices that would reduce ageing degradation rates;
- prediction of future performance (i.e. functional capability and remaining service live) of SSCs required for safe plant operation; and
- identification of new ageing effects before they can jeopardize plant safety.

Once the infrastructure for an AMP is in place, a systematic SSC selection process should be developed in order to ensure effective use of available resources. The selection process should ensure that all SSCs important to safety and that may be susceptible to ageing degradation are identified. These SSCs would then be included in the AMP. In addition to the selected SSCs, the selection process and criteria, as well as the information sources used in the process should also be clearly documented. The selected SSCs should then be subject to an ageing evaluation, the objective being to assess the potential effects of ageing on the intended functions of the SSC and to determine available mitigation measures. The ageing evaluation should:

- Identify potential ageing degradation mechanisms for the specific SSC;
- Assess the impact of ageing degradation mechanisms on SSC functions;
- Establish means to detect and monitor the extent and rate of SSC degradation for the specific ageing mechanisms;
- Specify acceptance criteria to ensure that the required integrity and functional capabilities of the SSC are maintained; and
- Establish means to mitigate ageing mechanisms and their effects (e.g., through maintenance, replacement, or changes in operating conditions).

Ageing evaluations should take information from other related plant programs into account. In addition, the results of operating experience, research and development, and available previous ageing evaluations (both generic and plant-specific), may be used; however, the applicability of the conclusions and recommendations of the evaluations to the particular situation being studied should be confirmed. The methodology used for the ageing evaluations, as well as the results of all ageing evaluations performed should be documented. If necessary, the ageing evaluation should provide recommendations for the application of the results of the ageing evaluation to operating procedures and limits, maintenance and surveillance programs as well as for design changes.

For certain major SSCs or component groups, in particular if they are long-lived components, a condition assessment should also be performed, in order to determine the current performance and condition of the SSC, compare the current performance and condition against the predicted ageing mechanisms and the identified acceptance criteria, and predict future performance, ageing degradation and if possible, the residual service live of the SSC. Based on the outcomes of this assessment, recommendations for follow-up corrective and preventive actions should be made.

Once ageing evaluations and condition assessments are complete, recommendations for SSC-specific ageing management activities should be compiled, documented and dispositioned in a timely manner. Recommendations that affect other plant programs, such as the chemistry, periodic inspection, maintenance and equipment qualification programs should be made available to these programs and responsibility for their implementation clearly defined. A confirmation process to ensure that adequate corrective actions and preventive measures have been completed and are effective is also necessary.

Finally, provisions for program review and continuous improvement should be implemented, including a process for assessing the effectiveness of the AMP over the lifecycle of the NPP. The information used, assumptions, conclusions and recommendations of the AMP evaluations should be periodically reviewed and updated in order to incorporate new information, to address new issues and operating experience, and to use more sophisticated tools and methods as they become available. Whenever an AMP deficiency is identified, its significance should be assessed, and where appropriate, a root cause determination and corrective actions should be undertaken.

INTERNATIONAL COOPERATION

CNSC staff is participating in a number of initiatives closely related to ageing management of NPPs through international organizations (IAEA, OECD/NEA) as well as cooperative projects with other nuclear regulatory agencies. CNSC participation in these activities provides an opportunity to harmonize our regulatory guidance approach and documents with international best practices and recommendations. Some of the international initiatives closely related to ageing management include:

Development of IAEA Safety Guide on Ageing Management (DS382) – The objective of this proposed IAEA Safety Guide is to provide a set of guidelines and recommendations for managing ageing of SSCs important to safety in nuclear power plants, including recommendations on key elements of effective ageing management and its implementation. The Safety Guide is intended to assist operators and regulators in establishing, implementing and improving systematic AMPs in nuclear power plants. This Safety Guide, in conjunction with CNSC Regulatory Standard S-334, may also be used in verifying that ageing in the nuclear power plants is being effectively managed.

Development of IAEA Guidance on Safe Long Term Operation of NPPs (DS335) – The purpose of this proposed IAEA Safety Guide is to provide guidance and recommendations on key technical considerations and activities to ensure safe Long Term Operation (LTO), taking into account approaches, best practices, and experience of Member States pursuing LTO. The presently available IAEA Safety Standards do not address LTO. The LTO guideline is intended to fulfill, in part, the need expressed by Member States for guidance, developed and agreed upon by international experts that may be referenced when developing national programs for LTO with focus on physical structures of NPPs. The development of this LTO safety guide supports CNSC regulatory documents in this area, e.g. G-360 on “Life Extension” and S-334 on “Ageing Management” as well as associated regulatory review processes.

NPP Life Management Processes – Guidelines and Practices for Heavy Water Reactors (TECDOC 1503) – This IAEA TECDOC [5] deals with organizational and managerial means to implement effective Plant Life Management (PLiM) into existing and future heavy water reactors. The objective of a PLiM program is to effectively integrate ageing management and economic planning to maintain a high level of safety, optimize operation, maintenance and service life of SSCs.

International Experience in Implementing Periodic Safety Reviews –CNSC staff has participated in a number of technical meetings on best practices and lessons learned in PSR implementation. CNSC is implementing IAEA PSR guidelines and best practices for the conduct of the Integrated Safety Reviews for life extension according to G-360.

Risk-informed In-service Inspection Methodologies (RISMET) – The RISMET program is an international program coordinated by the Organization for Economic Cooperation and Development (OECD) Nuclear Energy Agency (NEA) Working Group on Integrity of Components and Structures (IAGE). The overall objective of the project is to apply various methodologies of Risk-Informed In-Service Inspection to the selected cases in one nuclear power plant: The project will provide a comparative study aimed at identifying the impact of such methodologies on reactor safety and how the main differences influence the final result (i.e. the definition of the risk-informed inspection program); Compare the risk rankings obtained by different methodologies and evaluate the significance of differences in the results; Compare qualitative and quantitative Risk-Informed In-Service Inspection methodologies with traditional (deterministic) programs that are based on established classification of components; and the impact of the optimized In-Service Inspection Program on the reductions in radiation dose to workers performing (NDE) Non-Destructive Examination.

Stress Corrosion Cracking and Cable Aging (SCAP): The SCAP Project was initiated by OECD NEA IAGE with the aim of producing a database and knowledge base on ageing issues, with focus on stress-corrosion cracking and cable ageing, as well as commendable practices for ageing-management. Two subjects, i.e., stress-corrosion cracking and degradation of cable insulation were selected as the focus of this project, because of their relevance for plant-ageing assessments and implication on inspection practices. They also represent two areas where the states of knowledge as well as the inspection methods are quite different. Considerable information has been generated on SCC related events, including piping and component failure, and methodologies exist for SCC inspections and some mitigating measures. However, there is still a need to consolidate the acquired knowledge and experience into commendable practices. For cable ageing, the information on degradation-induced “events” or failures is limited and the inspection methodology is not yet well established.

These differences will necessitate that the two subjects of this project be addressed using separate approaches. Nevertheless, the overall project goals will be similar for both parts of the project and will ultimately consist of producing a database on operating experience, a knowledge-base on background information, requirements and methods, and a basis for commendable practices for ageing-management founded on an assessment of the available information.

The OECD Pipe Failure Data Exchange project (OPDE): The OECD NEA established the Piping Failure Data Exchange (OPDE) Project. The objectives of the OPDE Project include the establishment of a framework for multi-national cooperation in piping reliability. Initially a three-year program, the primary activities of the OPDE Project are to: Collect and analyze pipe failure data in order to promote a better understanding of underlying causes of failure, observed and potential impacts on plant operation, safety and prevention; Project participants that provide validated pipe failure data will gain full access to the OPDE database; Generate qualitative insights about the root causes of pipe failures; Establish a mechanism for efficient feedback of experience gained in connection with pipe failure and development of defences against pipe failure; and Collect information on piping reliability attributes and influence factors to facilitate estimation of pipe failure frequencies.

Maximizing Enhancements in Risk-Informed Technology (MERIT): As the technology associated with commercial nuclear power generation has matured, risk management has become one of the cornerstones behind the maintenance and operation of these plants. Over the years a number of risk-management tools have evolved to the point that they are now frequently used in the decision making process. On the other side, probabilistic risk/safety assessment (PRA/PSA) analyses are used by both the industry and regulatory staff. Risk-informed in-service inspection protocols are being incorporated into inspection criteria embodied in ASME Pressure Vessel and Boiler Code. Probabilistic fracture mechanics (PFM) codes, such as PRAISE and PRODIGAL, and databases of in-service operating experience are being used more to access potential risks associated with the operation of nuclear power plants. In order to further enhance some of these risk-management tools, Battelle launched an international research program, known as MERIT which is structured to build upon earlier highly successful programs, like IPIRG (International Piping Integrity Research Group) and BINP (Battelle Integrity of Nuclear Piping). MERIT program concentrates on addressing three focused disciplines with associated specific objectives: Continued development of a probabilistic fracture mechanics code PRO-LOCA for estimating the frequencies of various size loss-of-coolant accidents (LOCA); Assessment of weld residual-stresses and their impact on stress-corrosion cracking; and Continued development of a flaw evaluation criteria for Class 2, 3 and balance of plant (BOP) piping.

In addition, CNSC staff is actively involved in discussions with the nuclear industry on a number of research and development programs that industry supports through the CANDU Owners Group (COG). The Canadian nuclear industry is actively involved with the Electric Power Research Institute (EPRI) and Institute of Nuclear Power Operations (INPO) to share experience and best practices in operation of nuclear power plants.

PATH FORWARD

As previously mentioned, CNSC staff has undertaken the production of a Regulatory Standard S-334 to outline the regulatory expectations for NPP licensees' ageing management programs. The standard will reflect the key ageing management approaches outlined in the preceding sections, and emphasize the adoption of a life-cycle approach to ageing management as well as the establishment of a systematic ageing management program. Once published, the CNSC will initiate compliance review activities to assess licensee programs against these requirements, establishing a regulatory program to verify compliance with the new standard.

Recently, CNSC 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 and safety. CNSC staff is 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. CNSC staff is working closely with the industry to develop a separate CSA N285.7 Standard on Inspection of Secondary Side Systems Important to Safety. In addition, CNSC staff is actively involved in the development of another addition to CSA N285 family of Standards, one on risk-informed in-service inspection of safety-related components.

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 previous sections, 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 a pre-approved and audited procedure. CNSC staff foresee that an increased use of PBAs will result in improved regulatory effectiveness and efficiency, while reinforcing the CNSCs policy that licensees bear primary responsibility for ensuring the safe operation of NPPs.

SUMMARY AND CONCLUSION

The review of international practice as well of current domestic approaches identified the need to further enhance the current Canadian regulatory framework with respect to ageing management. The first priority is to ensure the implementation of systematic and integrated ageing management programs at nuclear power plants. Although currently programs are in place to address ageing at each of the Canadian nuclear power facilities, additional regulatory requirements and guidance is required to provide a common set of benchmarks to which these programs may be evaluated and to facilitate CNSC staff evaluations of industry performance in this area. The publication of a regulatory standard, along with other initiatives that CNSC staff are undertaking at both the national and international level, is expected to serve to provide adequate assurances that the ageing degradation of Canadian NPPs is being effectively managed such that sufficient safety margins remain, thus minimizing risks to workers, the public and the environment.

REFERENCES

1. Canadian Nuclear Safety Commission, “Reporting Requirements for Operating Nuclear Power Plants”, CNSC Regulatory Standard S-99, March, 2003.
2. International Atomic Energy Agency; “Implementation and Review of a Nuclear Power Plant Ageing Management Programme”, Safety Reports Series No. 15, Vienna, Austria, 1999.
3. Canadian Nuclear Safety Commission, “Life Extension of Nuclear Power Plants”, Draft Regulatory Guide G-360 Issued for public comment, May 2006
4. International Atomic Energy Agency; “Periodic Safety Review of Nuclear Power Plants”, Safety Standards Series No. NS-G-2.10, Vienna, Austria, 2003.
5. International Atomic Energy Agency; “Nuclear Power Plant Life Management Processes – Guidelines and Practices for Heavy Water Reactors”, TECDOC 1503, Vienna, Austria, 2006.

Table 1 – Age Distribution of Operating Canadian Nuclear Power Plants

Location	Unit	Gross Capacity MW(e)	Start-Up	Approx. Years in Service	Remarks
Pickering A, Ontario	1	542	1971	29	All units had pressure tubes replaced in 1980’s. All units placed in lay-up in 1997. Unit 4 returned to service 2003. Unit 1 returned to service 2005. Units 2 and 3 placed in safe shutdown state until decommissioning.
	2	542	1971	27	
	3	542	1972	26	
	4	542	1973	29	
Pickering B, Ontario	5	540	1983	24	In operation. Evaluating feasibility of refurbishment for LTO.
	6	540	1984	23	
	7	540	1985	22	
	8	540	1986	21	
Bruce A, Ontario	1	904	1977	21	Unit 2 placed in lay-up in 1995. Remaining units placed in lay-up in 1997. Units 4 returned to service 2003. Unit 3 returned to service 2004. Units 1 and 2 currently undergoing refurbishment for LTO.
	2	904	1977	19	
	3	904	1978	23	
	4	904	1979	22	
Bruce B, Ontario	5	915	1985	22	Operating.
	6	915	1984	23	
	7	915	1987	21	
	8	915	1987	20	
Darlington, Ontario	1	935	1990	17	Operating.
	2	935	1989	18	
	3	935	1993	14	
	4	935	1992	15	
Point Lepreau, New Brunswick	1	680	1983	24	Operating. Refurbishment for LTO in 2008-2009.
Gentilly, Quebec	2	675	1983	24	Operating.