MATERIAL DEGRADATION MANAGEMENT OF THE REACTOR COLLANT SYSTEM AT THE POING LEPREAU GENERATION STATION

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Abstract

In the past decade, the Point Lepreau Generating Station (PLGS) has experienced some serious degradation in the major components of the primary heat transport system[1] (HTS). Environmental cracking of PLGS carbon steel feeder piping, previously unknown in the industry, presented unique challenges and drove New Brunswick Power Nuclear (NBPN) to implement an aggressive and proactive life management program. The successful implementation of the feeder piping management plan has led to a similar approach for other components and for the HTS itself as a system.

Numerous documents have been published by organizations such as the International Atomic Energy Agency, Electric Power Research Institute, Nuclear Energy Institute, and the Institute of Nuclear Power Operations that provide generic and specific guidance for developing and maintaining processes for component life management. To ensure the anticipated benefits of the guidelines documents are realized, a significant number of operations and maintenance (O&M) activities must be identified and effectively implemented. Utilities and industry working groups strive to do this most effectively for their own needs, often working together to make best use of others' experience.

The continued development of the PLGS HTS materials degradation management program is based on industry guideline document principles. However, it has been the experience and best practices learned from other utilities, service providers, and within NBPN that has been key to the successful implementation of plans. This paper shares some of the most effective and practical features of the PLGS HTS materials degradation management program.

1. Introduction

Serious degradation of the major components of the primary heat transport system (HTS) is leading New Brunswick Power Nuclear (NBPN) to refurbish the Point Lepreau Generating Station (PLGS) several years prior to its design life and also to adopt a more aggressive and proactive HTS materials degradation management program (MDMP). Under continuous development by NBPN and AECL since 2003, this program has been successful in preventing failures, improving stakeholder confidence, and focusing maintenance resources on activities with the greatest benefits. The program is based on general prinicples common to many industry Plant Life Management documents, such as those from the International Atomic Energy Agency, Electric Power Research Institute, Nuclear Energy Institute, and the Institute

[1] The heat transport system in a CANDU reactor is equivalent to the reactor coolant syatem in a PWR design.

of Nuclear Power Operations. Equally important, practical means to implement these principals were developed based on interviews with industry personnel with materials degradation management experience. The purpose of this paper is to share the most useful and practical of these ideas.

1.1. Overview of Point Lepreau HTS and Degradation Issues

NBPN has operated PLGS since 1983 with a life-time capacity factor of ~83%. PLGS is a CANDU®[2] pressurized heavy water design with 380 individual fuel channel assemblies running horizontally through the reactor core's cylindrical calandria vessel. Each fuel channel is comprised of two concentric zirconium alloy tubes. An inner pressure tube carries the fuel bundles and pressurized reactor coolant and an outer calandria tube separates the heavy water moderator in the calandria vessel from the pressure tube. Four loose garter springs in the annulus maintain separation between the two tubes in each channel. PLGS has four recirculating steam generators with alloy 800 tubing. Primary reactor coolant is carried through the heat transport system (HTS) between the fuel channels and the steam generating system by 380 carbon steel feeder pipes and four headers, each for inlet and outlet flow. Figure 1 shows a schematic view of one reactor face with the insulation cabinet removed. All fuel channels and feeder piping will be replaced during an eighteen-month Refurbishment Outage beginning in 2008. The current steam generators will remain in service for a total expected operating life of about 55 years.

A significant and fluctuating percentage of NBPN's operations and maintenance (O&M) budget has been directed at managing materials degradation issues for the three major HTS components: feeders, fuel channels, and steam generators. The major costs are due to lost production, planned and unplanned corrective maintenance, and engineering to demonstrate safe operation, design changes, response to regulatory requirements, personnel radiation exposure, and maintaining good public relations. Self-assessments indicated that inefficient processes were responsible for many unnecessary costs [1].

Degradation of feeders was the driver for an improved HTS materials degradation management program in 2003. Feeder pipe thinning from flow accelerated corrosion (FAC) occurs in all CANDU reactors and is life limiting in some PLGS outlet feeder bends. However, environmental cracking from the inside and outside surfaces coincident with wall thinning [2] is unique to PLGS and has led to concerns that leak-before-break would not always be the mode of failure. Figure 2 shows an environmental crack through the scallops produced from FAC on the inside surface of a PLGS outlet feeder bend.

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[2] CANDU (CANadian Deuterium Uranium) is a registered trademark of Atomic Energy of Canada Ltd.

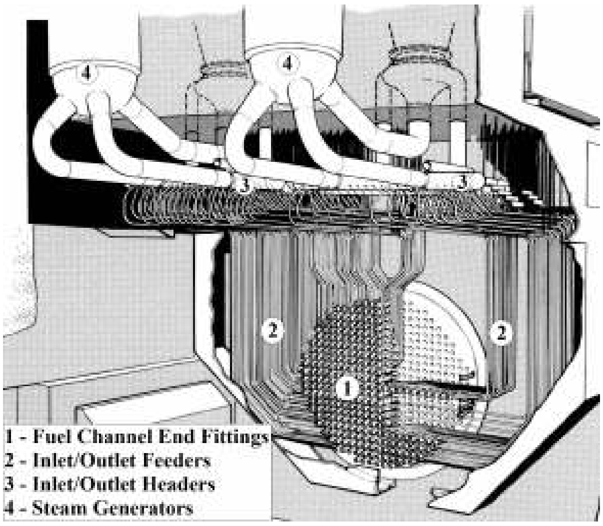

FIG. 1. Layout of the CANDU® HTS.

FIG. 2. Inside Surface of Degraded Feeder

In addition to feeder issues, significant costs have been incurred to manage steam generator degradation [3] (fouling, localized corrosion and fretting of tubing, FAC of internals) and pressure tube issues [1] (diametral creep which leads to flow-by-pass around the fuel, and delayed hydride cracking from pressure tube-to-calandria tube contact when garter springs move out of position).

1.2. Approach Based on a Review of Resource Information

To apply industry best practices to the development of the PLGS MDMP, international industry guidance documents and regulations for ageing and life cycle management were reviewed. It was found that many industry guidance documents have a generic and broad scope for addressing plant-wide issues. Guidance for developing specific O&M activities to implement guideline goals and objectives are not normally included. Most documents focus on common components and ageing and are not optimal for the most serious PLGS HTS degradation, which is random and isolated (e.g. fuel channel garter spring movement and feeder cracking). On the other hand, regulations are often very specific and not applicable to PLGS issues. In cases where the regulator is prescriptive and/or risk averse, station programs focus on demonstrating compliance with rules and regulations.

Overall, it was found that the Nuclear Energy Institute Guideline for the Management of Materials Issues, NEI 03-08 [4] prepared following the Davis-Besse vessel head corrosion experience, was most easily adaptable for managing PLGS HTS materials degradation. It provides the most specific materials degradation management guidance and also includes implementation aspects.

In addition to the review of documents, experienced personnel were interviewed at working group meetings, seminars, conferences, and during benchmarking visits to three Nuclear Power Plants (NPP) in the USA and two in Europe. Excellent advice was received from numerous personnel from utilities and service providers about implementation issues and best practices.

Based on a review of these resources, the following approach was selected for the PLGS MDMP:

- Use existing station processes for establishing and implementing maintenance programs that are based on INPO AP-913 [5].
- Satisfy the intent of NEI 03-08, Guideline for the Management of Materials Issues.
- Use best practices for implementation based on ideas from experienced personnel.

2. Key Features of the HTS Materials Degradation Management Program

The purpose of the MDMP is to correct inefficient processes identified from the self-assessments, to make additional improvements that meet the intent of NEI 03-08, and to ensure that the risks from HTS component degradation are low and comparable with other plant equipment. Much of this purpose is being advanced by improved implementation of technical information, applying risk-based decision making, and by improved integration of management activities. This main section shares the most useful and practical features of the PLGS HTS MDMP. It does not include all important plan elements, only those where significant improvements were made over common practice.

2.1. Integration of Management Activities

Management activity integration has been improved by using a program structure comprising a system-level HTS materials degradation management plan and sub-program plans for individual components and multi-system functions and issues. The concept is modeled after a mandatory requirement for an 'overarching' system-level plan in NEI 03-08. The sub-program plans were categorized as mandatory, needed, and good practice to be consistent with NEI 03-08 approach for determining implementation levels. The following criteria were used to assign the implementation categories:

- Mandatory – shall be implemented.
  - Degradation affects the ability of components to perform their intended safety function.
  - Not implementing a management strategy would be highly risk significant.
  - There is significant threat to continued operation of the plant and protracted plant shutdown or retirement is considered possible.
  - Required to satisfy a license condition.

- Needed – should be implemented, but alternate approaches are acceptable.
  - Degradation affects the ability of components to reliably perform their economic function.
  - Not implementing a management strategy would be moderately risk significant.
  - Management strategy addresses material degradation that has significant financial impact on the industry, especially where failure at PLGS could affect many others.

- Good Practice – implementation is expected to provide significant operational and reliability benefits, but is at the discretion of the Station Management.
  - Degradation has a low likelihood to affect the design function of the components.
  - Management strategy reflects an industry standard of performance.

The program structure and sub-program plan implementation categories are shown in Table 1. Overarching plans have been mandatory for plants in the USA since 2006 but they are not mandatory in Canada. PLGS prepared the first overarching CANDU HTS plan to make the improvements discussed in the following subsections.

2.1.1. Provide Formal Interfaces

The overarching HTS plan provides a formal interface between the feeder, fuel channel, and steam generator plans and other station processes. Tables that provide simple and quick references for the system engineers are used in the plan. The tables identify clear interfaces between station processes, plans, and work groups to ensure that:

- Maintenance activities are performed to support the management of system-level degradation.
- Maintenance activities are performed on components to provide information that is required for condition assessment of other components.
- The system chemistry and operating parameter ranges and limits required to reduce the risk from materials degradation for specific components are clearly identified so they do not adversely affect other system components.

2.1.2. Identify System-Level Operating Requirements

The overarching HTS plan identifies system-level operating requirements (operating procedures that affect all system components) to protect specific components that have the potential to affect other components or system-level degradation mechanisms. It is important for O&M plans to consider the interrelationship between component and system-level degradation issues, since:

- Degradation of individual components can affect the performance of the full system
- Individual component management that employ system-operating strategies could have a negative effect on other components.

For example, a low primary coolant dissolved hydrogen concentration is specified to minimize the risk of pressure tube delayed hydride cracking whereas a higher level is required to reduce the risk of feeder cracking. Another example is the reactor warm-up procedure which is a compromise to meet requirements to avoid pressure tube delayed hydride cracking and fatigue cracking of steam generator lateral restraints.

Table 1. Organization of MDMP Sub-Program Plans

Overarching Program	**HTS Material Degradation Management Plan**		
Implementation	**Mandatory** ***Shall be Implemented***	**Needed** ***Should be Implemented***	**Good Practice** ***Discretionary***
Approval Required for Deviations from Program Plans	Technical Manager	Systems Performance Superintendent	Systems Performance Superintendent

HTS Sub-Program Plans	Feeder Piping Management Plan Fuel Channel Management Plan Steam Generator Management Plan		Maintenance Response to Chemistry Transients Plan[†]
Multi-System Sub-Program Plans	Periodic Inspection Program Plan Pressure Vessels Program Plan	Flow Accelerated Corrosion Fatigue Monitoring[†]	
Non-Maintenance Sub-Program Plans, Operations Documents, and General Documents	Feeder Cabinet Leak Detection Annulus Gas System Leak Detection H2O/D20 Leakage Detection D_2O in H_2O Leak Detection System Steam System Pressure Control Failed Fuel Location System	HTS Chemistry Optimization Plan Rationale for Chemistry Control and Optimization Plan for the Steam Cycle Foreign Materials Exclusion	Operating Guidelines to Minimize Materials Degradation Plan[†]

[†] Under development.

2.1.3. Manage System-Level Degradation Issues

Degradation of individual HTS components also contributes to system level degradation issues that affect the function of the HTS. The primary HTS function is to provide heat transfer from the fuel to the steam generators, pressure and inventory control for the coolant, and fuel cooling under design and accident conditions. The system is also required to prevent unacceptable release of radiation and to minimize radiation exposure to the workforce. The overarching HTS plan identifies sub-program requirements for addressing three system level issues that are not managed explicitly in any sub-program plans:

— *Breach of Pressure Boundary*. Through-wall degradation of any HTS component requires a system-level response to mitigate the consequences and maintain fuel cooling and heavy water inventory and to prevent consequential failures and release of radioactive materials.

— *Increased Radiation Fields*. The transport and out-of-core deposition of radionuclides onto various HTS component surfaces increases the radiation fields and worker exposure. The sources of these radionuclides are primarily from fuel failures and activated corrosion and wear products (e.g. Zr, Nb, Co) from system materials.

— *Flow Bypass*. This term refers to the decrease in capability of the coolant to transfer heat from the fuel to the steam generators as a consequence of component degradation affecting thermalhydraulic efficiency (e.g. diametral pressure tube creep, steam generator tube fouling). The concern with flow bypass is an increased risk of fuel dry-out, which requires reactor de-rating to maintain adequate Reactor Overpower Protection margins.

2.2. *Improved Implementation of Technical Information*

It was observed that responsible engineers often preferred to implement inspection and maintenance activities using spreadsheets instead of life management plans. The most common reasons cited were that plans were excessively lengthy and contained superfluous information, information was not presented in a format that was recognized as useful, and other important practical information was missing. As a result of these issues, critical technical information was not always considered in materials degradation management planning and that sometimes, important planned activities were not being performed [1].
Based on feedback from utility staff, the following improvements were made to more effectively implement technical information into O&M activities.

2.2.1. *Consistent, Practical Plan Format*

The following format features have been most effective:

- Plans are kept to less than ~40 pages so that they are easy to use and update. Plans contain only the most relevant information to the risk management strategies and activities. Supporting technical justification is referenced.
- Responsibilities and definitions are defined in the overarching plan and are not repeated in each sub-program plan document.
- Each plan defines the level of approval required for deviations to the plan (illustrated in Table 1).
- Each plan identifies required interfaces between other station workgroups and processes.
- Management activities are planned based on the concept of risk-reduction and using a simple Risk Management Index described in Section 2.3.1.
- Plans identify the link between the risks of degradation and specific management activities (Section 2.2.3).
- Sub-program plans include pre-determined response plans to anticipated inspection findings. An example is given in Section 2.2.4.
- Each plan clearly identifies acceptance criteria, mandatory maintenance, and regulatory commitments.
- Plans include a detailed short term scope and schedule and a more general long term schedule.

The general format for the overarching HTS plan and sub-program plans are essentially the same. The main difference is that the overarching plan identifies the requirements for sub-programs, which in turn set out the requirements for the scope and schedule for specific O&M risk management activities. The sub-program plans are used to identify work that is controlled by the Station's work managements system. The general plan layout and contents is presented in Table 2.

Table 2. Contents of Management Plan Documents

Section	Sub-Section
Introduction	Purpose and Scope, Governing References, Specific References, Supplementary References, Responsibilities, Definitions
Design Basis Review	Program Scope, Operating Limits, Design and Performance Requirements, Considerations from the Nuclear Safety Analysis
Requirements for License and Regulatory Compliance	License Requirements, Mandatory Maintenance, Reporting, Acceptance, and Disposition Criteria, Acceptance Criteria for Probabilistic Safety Evaluations, External Agency Action Items and Commitments
Operating Experience	Relevant Internal and External Operating Experience
Dominant Failure Modes and Degradation Mechanisms	Active and Potential Degradation Relevant to Plan – described in Section 2.2.2.
Management Plan Options	Strategy for the HTS Materials Degradation Management Plan, Management Plans Based on Risk-Reduction
Recommended Sub-Program Plans (or O&M Activities)	Identification and Implementation of Program Plans, Overview of the HTS MDMP Organization and Deviations, Interfaces to Manage System-Level Degradation Issues
General	Strategy for Mitigating Ageing Issues, Required Maintenance Documentation, Recommended Design Changes Monitoring and Trending Requirements, Qualification and Training Requirements

2.2.2. *Identification of Relevant Degradation*

It is important to identify active and potential degradation mechanisms that, if not managed effectively, can result in an unacceptable level of risk to reactor safety and reliability. For credible degradation mechanisms, each plan briefly identifies and assesses pertinent information from operating experience, plant monitoring data, and research programs to determine the dominant degradation mechanisms, in the following manner:

— *Description of the degradation mechanism and the key factors that affect the degradation.* The key factors affecting degradation are most important for this section and they can often be identified even if the fundamental details of the degradation mechanism are not known. An example is given for feeder cracking in Table 3. The development of mitigation strategies is highly dependent on the potential to minimize or eliminate one or more key factors.

— *Identification of locations that are most susceptible to the degradation.* Knowledge of the presence of key factors in different system locations and during different operating conditions is required to establish the likelihood of degradation for these cases.

— *Evaluation of Operating experience.* Plans include a brief summary of relevant internal and external operating experience. Operating experience is important to determine the current condition of components and, in addition to the above, to assess the possibility of degradation ocuring in future. It is important to also consider positive operating experience. It was found that positive operating experience, such as inspection results that did not detect feeder cracks or garter spring movement, was not always given adequate consideration in assessing the likelihood of degradation.

— *Statement of the management concern if the degradation is not adequately managed.* In PLGS plans, this section identifies qualitative consequences of degradation (e.g. perforation of the pressure boundary or unplanned shutdown for repair) but quantitative information could also be used. This section is important to establish the risk of degradation and the risk reduction of an activity employed to manage it.

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Table 3. Factors Contributing to PLGS Feeder Cracking

Primary Factors	Secondary Factors
<u>**Stress:**</u>	
Residual Stress: Based on physical evidence from spare bends and cracked feeders.	**Operating Stress**: Low amplitude cyclic stresses and other operational stresses postulated to increase susceptibility. No physical evidence.
<u>**Material:**</u>	
Cold Work/Hardness: Factors associated with observed cracks.	**Ovality and Impurities**: Postulated, based on operating experience and literature.
<u>**Environmental:**</u>	
Temperature: Cracks only in outlet feeders where temperature is 40°C higher than in inlets. Consistent for creep cracking which is highly dependent on time at temperature (usually >310°C).	**FAC-Generated Hydrogen**: Consistent with all crack locations; proposed to contribute to crack susceptibility. **Oxidizing Species and Impurities**: Based on literature and test results showing SCC in mildly oxidizing hot water (>100-150°C), exacerbated by anionic impurities.

2.2.3. Raise Awareness of Reasons for Management Activities

One means that the MDMP increases the likelihood that O&M activities are given appropriate priority, particularly when unexpected events or schedule changes occur during outages, is to raise awareness of their importance with the responsible engineer. This is done using easy reference tables in the overarching plan and sub-program plans that link O&M activities to system-level and component materials degradation management strategies. Examples are given for flow accelerated corrosion in Table 4.

Table 4. Table Used to Show the Link Between the Degradation Mechanism, System-Level Issues, Management Options, and Risk-Reduction Activities.

(a) Example from the HTS MDMP for Flow Accelerated Corrosion

Degradation Mechanism	HTS MDMP Strategy		
	Major Affected Components	**Relevant System-Level Issue**	**Management Options**
Flow Accelerated Corrosion	Outlet Feeders	Coolant temperature increase Decreased fuel cooling margins Increased radiation fields System chemistry limits	Inspection & Repair, Chemistry Control
	Large diameter outlet piping and headers	N/A	

	Steam generator internals	N/A	

(b) Example from the Feeder Piping Management Plan for Flow Accelerated Corrosion

Degradation Mechanism	Primary Strategy to Manage Degradation		
	Affected Components	Management Option	Management Activities
Flow Accelerated Corrosion	All outlet locations, especially tight radius bends & adjacent to Grayloc Hub	Inspection	Wall thickness measurements
		Repair	Replace components projected to thin below minimum acceptable thickness
		Chemistry Control	Control pHa to lower end of specification (10.2-10.4) to minimize FAC rate

2.2.4. Pre-Determined Response Plans to Findings

Pre-determined response plans for possible findings from planned inspection and maintenance activities have been a very effective feature of the MDMP sub-program plans. The advantage is more immediate awareness of potential results that may challenge the current basis for safe operation. Knowledge of this situation early in an outage allows for prompt initiation of activities (e.g., inspection scope expansion) that will decrease the likelihood of an outage extension. Following pre-determined response plans also increases credibility with Management and Regulators.

Response plans are developed using the results of operational assessments from the previous inspection. Probabilistic assessments are particularly useful for developing response plans [6] because they allow sensitivity analysis of several parameters using best estimates. Table 5 shows an example from the feeder piping plan. The information that is obtained during feeder crack inspection is approximate crack length, crack location, and the number of cracked feeders. The table lists potential inspection findings for these crack characteristics that would challenge the basis for inputs (initiation frequency, crack growth rate, key factors initiating cracks) used in the previous operational assessment. This information was used to identify actions required during and immediately following the outage.

Table 5. 2007 Outage Response Plan for Feeder Piping Crack Inspection.

Cracked Feeders in 2007	Max. Crack Length	Condition Assessment Valid	Impact on Inspection and Maintenance Strategy
Reportable Inside or Outside Surface cracks in Outlet Tight Radius Bends:			
0-6	~25mm	Yes	No supplementary activities or changes to the plan required. Remove requirement for crack inspection during an unplanned shutdown.
>6	~25mm	Review required	No inspection scope expansion. Prior to reactor restart, assess the validity of the condition assessment.

>0	>30mm	Review required	No inspection scope expansion. Perform NDE to characterize indications after feeders are removed. Depending on the severity of the cracks, destructive examinations to assess the validity of the condition assessment may be required prior to reactor restart.
Reportable Cracks in Other Locations:			
0	N/A	Yes	No supplementary activities or changes to the plan required.
>0	N/A	No	If cracks are found on an inlet bend, expand scope to all inlet first and second bends; operational assessment required prior to reactor restart.
>0	N/A	Review required	If circumferential cracks are found in a thinned region adjacent to the Grayloc hub, expand scope to other at-risk locations.

2.3. Application of Risk-Based Decision Making

A primary goal of the HTS MDMP is to provide cost-effective risk-reduction to a known or perceived risk to the safe reliable operation of the plant. Historically at PLGS, resource allocation to manage HTS materials degradation has been based on the judgment of maintenance engineering staff. Since 2003, for most activities in the MDMP, risk-based decision-making is being implemented qualitatively using a Risk Management Index (RMI). For the most serious degradation, this is being done quantitatively using probabilistic safety evaluations. The implementation of these is described in the sub-sections below.

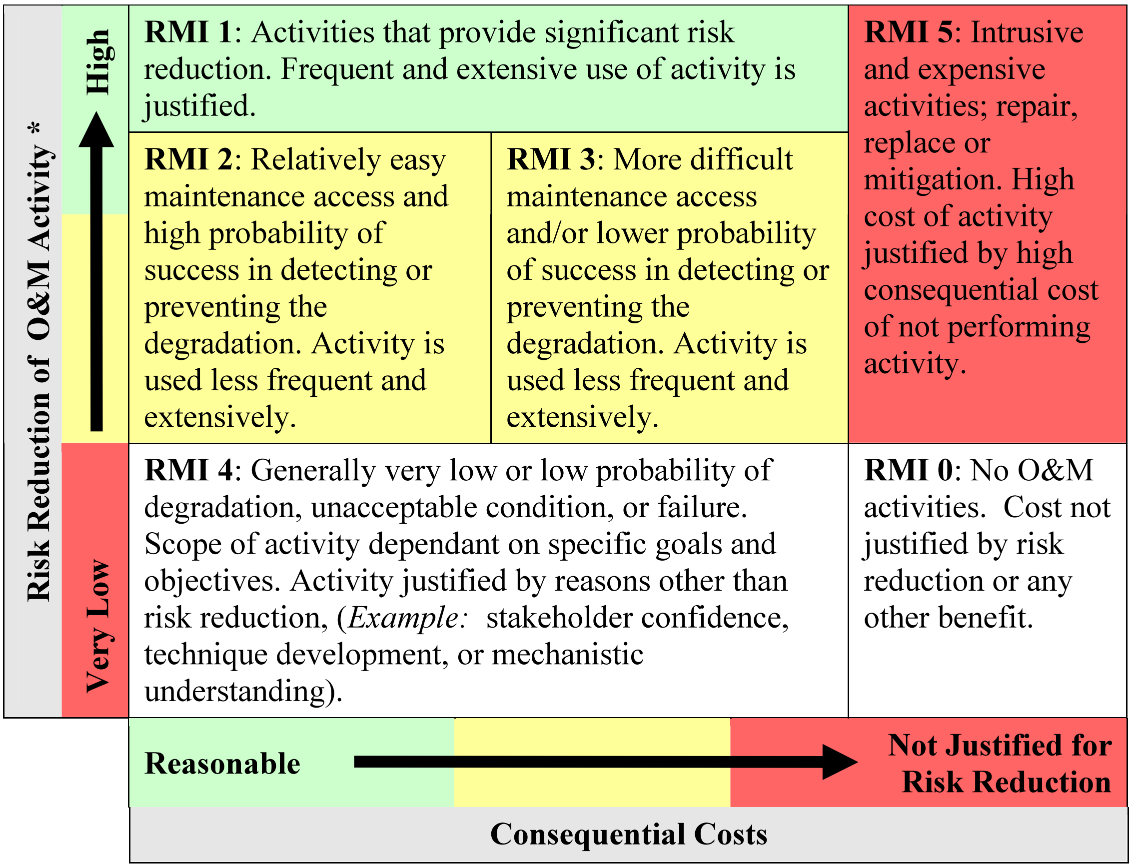
2.3.1. Risk Management Index – Qualitative Allocation of Resources

The RMI was developed to provide a simple and consistent qualitative methodology to evaluate the potential benefits of different management activities using the concept of risk-reduction. Unlike the concept of risk, which considers only the probability and consequence of degradation, the concept of risk-reduction also considers the impact of an activity employed to minimize that risk. It considers the likelihood that the activity will be successful and also the consequential costs of performing the activity. Consequential costs include worker hazards (e.g. radiation exposure), monetary expense, and the potential to cause other degradation to the component or system (e.g. foreign material ingress). The RMI levels and rationale are shown in Figure 3.

The RMI is used to make consistent, risk-informed selections of management activities and their scope, to obtain optimum and economic reduction in risk. In general, the strategy results in the following:

- For RMI 0, there are no program or management activities required.
- For programs or management activities evaluated as RMI 1 and 2:
  - Establish specific sub-program plans (Example: Feeder Piping Management Plan) with comprehensive technical support.
  - Plan extensive and frequent use of a management activity (Example: inspection).
- For programs or management activities evaluated as RMI 3 and 4:
  - Utilize existing station programs and processes to coordinate management activities (Example: Periodic Inspection Program for inspection of large bore piping welds).
  - Plan management activities based on sample selection and/or are less frequent.

— For RMI 5, programs and management activities are on a case-by-case basis.



* Considers risk of the degradation and the likely success of the activity to minimize that risk

FIG. 3. Illustration of the simplified method to evaluate risk reduction of O&M activities using the Risk Management Index.

2.3.2. Calculated Change in Severe Core Damage Frequency - Quantitative Allocation of Resources

In recent years, PLGS has used probabilistic evaluations to evaluate some of the more serious materials degradation issues using change in severe core damage frequency (ΔSCDF) as a safety criterion [6]. One of the primary advantages of using a probabilistic approach is the ability to quantify the risk-reduction provided by various management activities. Evaluation of inspection scope and inspection interval options has been the major application; however the probabilistic models have also be used to determine where to focus research, engineering, and development work to optimize the risk-reduction for an individual component degradation mechanism.

ΔSCDF acceptance criteria in applicable CANDU industry standards or industry guidance documents are applied. If there are no industry criteria available, the acceptance criterion is based on the risk-informed criterion of U.S. NRC Regulatory Guide 1.174[3] [7]. A specific criterion is required to be defined in the relevant HTS sub-program plan document.

When probabilistic assessments were performed for multiple components, it was recognized that a common safety criterion would also provide an effective means to assess and balance resource allocation for managing degradation of different components. The intent is to ensure that significant effort is not expended to reduce the contribution to SCDF of one type of degradation several orders of magnitude below another. Figure 4 provides the results of probabilistic safety evaluations for activities used to manage delayed hydride cracking of pressure tubes (in contact with calandria tubes) and feeder cracking. The results show that there is a reasonable balance being achieved since these risks are within a factor of four of each other and both contributions are within an order of magnitude of the USNRC criterion ($1x10^{-6}$ per year).

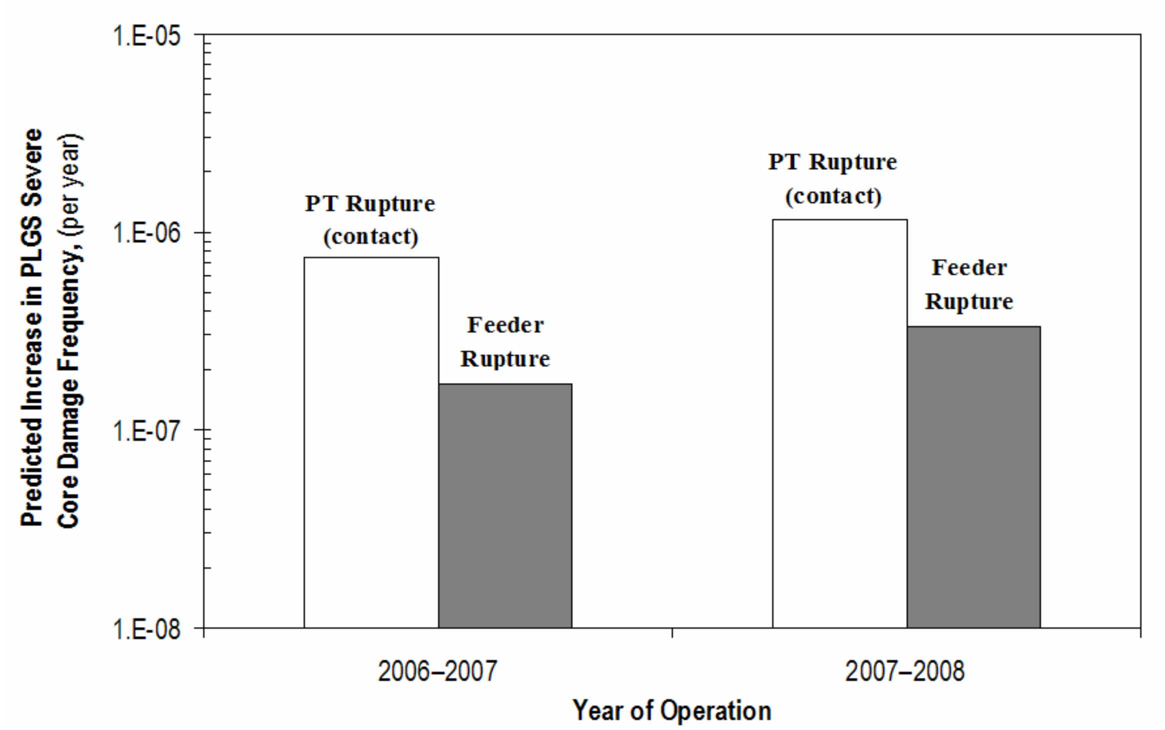


FIG. 4. Comparison of ΔSCDF Calculated for Feeder Pipe Cracking and Delayed Hydride Cracking of Pressure Tubes in Contact with Calandria Tubes [6]

3. Concluding Remarks

Improvements made to the PLGS HTS Materials Degradation Management Program since 2003 have brought tangible benefits: reduction in unplanned maintenance, lower budget required to address emerging issues allowing focus on improvement activities, and improved stakeholder confidence (regulators, NBPN staff and management, insurance providers).
This approach has been successful at PLGS for several reasons. A more systematic, risk-based approach has allowed NBPN to focus resources on activities that provide the greatest risk-

[3] US NRC Regulatory Guide 1.174 has been applied in the U.S. for evaluating the acceptability with respect to nuclear safety of strategic plans for managing materials aging degradation of primary pressure boundary components in PWRs.

reduction. A lot of emphasis was placed on human factors that affect the engineering staff responsible for managing HTS materials degradation. A primary focus of the MDMP was to make it easy to use. Practical information (regulatory requirements, contingency plans, acceptance criteria, etc.) is provided in easy-to-use reference tables. Where possible, existing station processes were used. Because this approach focuses on implementation aspects, is being used more effectively by PLGS engineers and therefore, the MDMP is being more successful at meeting intent of industry guidance documents.

The approach presented on this paper, based on NEI guidelines and operating experience good practice easily applied to any plant design.

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