STREAMLINED RELIABILITY CENTRED MAINTENANCE (RCM) APPLICATION TO CANDU 6 STATIONS

R. A. Richard, M. N. S. Holmes, J. H. Nickerson
Atomic Energy of Canada Limited
2251 Speakman Drive
Mississauga, ON L5K 1B2
Canada

A. L. DeLong, New Brunswick Power Corporation
Point Lepreau Generating Station
122 County Line Road
Maces Bay, NB E5J 1W1
Canada

Abstract

Over the past five years, Atomic Energy of Canada Ltd. (AECL) has been working with CANDU utilities on Plant Life Management (PLiM) programs that will see existing CANDU plants through their design life and beyond. As part of this initiative, AECL and New Brunswick Power have partnered to develop a Systematic Approach to Maintenance program applied to selected critical plant systems.

This paper will describe how streamlined Reliability Centred Maintenance (RCM) techniques have been applied on systems at the Point Lepreau Generating Station to provide a sound documented basis for maintenance strategies. These strategies have emphasised a hierarchy of condition based maintenance, time based maintenance and, where appropriate, corrective maintenance.

The major steps in the process are described. The clear benefits of focusing maintenance in areas where it is needed and effective from the context of impact on system function requirements are described. The basis of the maintenance program is fully documented at the individual task level. The results of the program are also used to define maintenance strategies for future CANDU power plants.

1.0 Introduction

Commercial power generation versions of CANDU reactors were put in service more than 25 years ago, and the first series of CANDU 6 plants (which entered service in the early 1980's) have now reached the middle of the their 30 year design life. Over the past five years Atomic Energy of Canada Limited (AECL) has been working with utilities on the CANDU Plant Life Management (PLiM) programs that will see the existing CANDU plants through their design life and beyond. As part of this initiative New Brunswick Power have partnered to develop a Systematic Approach to Maintenance program As a result a comprehensive and integrated CANDU Plant Life Management Program has been developed.

As part of this initiative, a Systematic Approach to Maintenance is being developed on selected critical plant systems. Strategies of condition based maintenance, preventive maintenance, or, where appropriate, corrective maintenance are defined based on the results of Streamlined Reliability Centred Maintenance (RCM) analysis. The most significant progress in this area has been the application of this strategy to optimise maintenance at the Point Lepreau Generating Station. Atomic Energy of Canada Ltd. and New Brunswick Power have been working in close co-operation on this project.

2.0 Streamlined Reliability Centred Maintenance Methodology

The streamlined RCM approach has been extensively used to perform maintenance optimization in the nuclear industry in Canada, Europe and the USA. The application of streamlined RCM provides the tools and performance indicators to measure the maintenance effectiveness and efficiency. It also provides a documented basis for each recommended maintenance task performed on every component in the analyzed system. It also provides a scientific basis for changes to maintenance program that require regulatory approval. AECL utilises SRCM Workstation™ Version 4.0 software developed by ERIN Engineering and Research Inc. of the USA.

The streamlined RCM process is applied to nuclear power plants assets in close consultation with plant engineering and maintenance staff. This ensures that plant experience and expertise are fully exploited to ensure validity of the streamlined RCM results. This also allows plant personnel to understand and "buy-into" the process. This is vital as plant personnel will ultimately be responsible for implementation and future program improvements.

Following is a description of a typical Systematic Approach to Maintenance study as outlined in Figure 1.

<u>2.1 System Definition/Boundaries:</u> Since streamlined RCM is applied to individual CANDU systems, the first step in the process is to define the systems to be analyzed including a definition of system boundaries with respect to interfacing systems. The system boundary must be a logical demarcation that includes equipment and components having similar functions, while clearly separating it from all interfacing systems. This is used to prevent duplication and ensure comprehensive coverage of interfacing systems without gaps.

<u>2.2 Plant History Review:</u> This step involves review of the following items to develop a list of issues to be resolved with the designated plant staff:

- Current system surveillance monitoring
- Current maintenance practices

- System operations and maintenance history
- Modification to system design/configuration
- Vendor recommendations

This review is performed to identify problematic components, areas where maintenance strategies are effectively mitigating failure causes, and areas where maintenance strategies are attempting to correct design or operational deficiencies.

2.3 Identify System Functions: Perhaps the most important step in the process is to identify the system functions and the required standard of performance. Both primary and secondary functions are defined. The primary functions of a system refer to the specific roles intended of the system in the overall safe operating context of the generating station. Secondary functions are those which are generally intrinsic to the system required to ensure that the primary functions are met, i.e. environmental protection, conventional safety, start-up, control, monitoring and shut-down.

2.4 Functional Failure Analysis: Once the system functions are identified, the analyst then identifies how each function can fail. A functional failure represents the inability of the system/subsystems to perform a function to the desired standard of performance.

2.5 Failure Modes and Effects Analysis: For each functional failure, a qualitative failure modes and effects analysis (FMEA) is performed. This analysis identifies the most plausible failure modes of the components involved and determine the effects of each failure mode. This assessment is largely based on engineering judgement, system maintenance history and industry experience. The analysis is "streamlined" to avoid unnecessary expenditure of resources to analyse the system at too low a level.

2.6 Criticality Analysis and Task Selection: Based on a systematic assessment of each failure effect, the importance (criticality) of the component is determined. In general, if the effect of failure on system function cannot be tolerated, then the subject component is deemed "critical". Where practical and effective, condition based maintenance (CBM) strategies are defined. Otherwise time-based failure finding or preventive maintenance tasks are defined.

Components whose failure effects on the system can be tolerated are deemed "non-critical". For such components, the decision to apply applicable preventive maintenance tasks is based on a cost-benefit assessment. If the cause of failure can be addressed through a simple and cost effective PM task, then the PM task is applied. Otherwise, it is acceptable to apply corrective maintenance for non-critical components as and when they fail.

Figure 2 outlines the maintenance strategy decision process. The process can also determine candidates for redesign where unacceptable failures cannot be effectively prevented with a maintenance task.

At this stage of the analysis, the team reviews the criticality analysis based on FMEA tables and recommended CBM and PM tasks from the streamlined RCM work, with designated plant staff. Any outstanding issues are resolved through mutual discussion.

2.7 PM Task Comparison and PM Program Modification: The results of the streamlined RCM analysis are compared with the existing preventative maintenance system (PMS) to identify needed changes.

Recommendations may involve adding tasks not yet performed. Current maintenance tasks are retained if effective, modified where they can be made more effective, or deleted if they are redundant or ineffective. A documented basis is provided for all changes.

The resultant maintenance tasks are grouped into task packages based on suggested work group responsibility and frequencies for ease of work definition and program implementation.

2.8 System Surveillance Matrix: A system surveillance matrix, which summarises the monitoring and trending tasks to be performed by the system engineer, is also developed. The surveillance matrix is defined by identifying degradation indicators for each system functional failure mode. System parameters which can be trended to give an indication of the degradation are identified. Parameter acceptance bands with appropriate actions are prescribed. The system surveillance matrices include both direct (process parameter) and indirect (maintenance backlog) indicators.

2.9 Implementation: Station personnel are involved in the streamlined RCM process at various stages. This is done to ensure that basis for the maintenance tasks are sensible and defensible. It also exposes the plant staff to the optimized maintenance strategies and allows for buy-in from the key personnel responsible for final implementation. All the recommendations also require formal approval from the managers with overall responsibility for the plant assets.

At the end of the streamlined RCM study the following items are available to ease implementation:

- maintenance tasks and schedules sorted by responsible work groups.
- system surveillance matrices
- clearly documented basis for each maintenance task
- a list of one-off changes such as procedure or design changes.

It is imperative to implement the recommendations as soon as practicable while personnel involved in the program can still easily recall specific decisions made. The sooner the results are implemented, the sooner the plant derives the full benefits of the analysis.

Changes in plant operation or design could impact on the effectiveness of the maintenance strategies defined. Also, quick implementation will ease the establishment of a living program for continuos improvement.

2.10 Living Program: As with any maintenance optimization strategy, streamlined RCM uses knowledge of past and present maintenance experience and industry knowledge. With time, knowledge of degradation mechanisms and maintenance technologies improve. Also changing operational demands or practices may present a change in system function or required standard of performance.

The streamlined RCM analysis and maintenance task basis must be reviewed periodically to ensure they remain valid and improved knowledge is captured and exploited. The basis for the maintenance program will be preserved, even in the event of staff turnover, allowing for legacy maintenance strategies to be compared fairly against emerging technologies and maintenance trends.

3.0 streamlined RCM Studies for Point Lepreau Generating Station

To date nine (9) streamlined RCM studies have been performed on systems at New Brunswick Power's Point Lepreau Generating Station.

- Auxiliary Feedwater System
- Airlocks and Containment Sealing Door
- Dousing System
- Containment Isolation System
- Reactor Building Cooling System
- Class III Standby Diesel Generator System
- EPS Diesel Generator System

- Main Feedwater System
- Condensate System

The following streamlined RCM studies are presently underway:

- Shutdown Cooling System
- Moderator and Auxiliary Systems
- Emergency Core Cooling System
- Instrument Air System

Up to four (4) more system streamlined RCM studies are planned for Point Lepreau G.S. in the near future, and it is planned to complete the balance of the systems over the next two years.

4.0 Sample Study - Point Lepreau G.S. Airlocks

This section summarizes the results of the streamlined RCM based maintenance optimization program to develop and document an applicable, efficient and cost-effective preventive maintenance program for the Equipment Airlock (EAL), Personnel Airlock (PAL) and Containment Sealing Door (CSD) Systems.

The conclusions and recommendations of this study were :

- The testing frequency of Equipment Airlock door penetration shaft seals should be changed from once every 4 weeks to once every 13 weeks. This would be consistent with an identical test being performed on the Personnel Airlock with good results.

- The replacement of the new inflatable door seals should be based on the number of cycles derived from qualification testing. This will require necessary measurement of door operation cycles and setting up the control process.

- Consideration should be given to replace the existing seal air pressure switches with a more appropriate range. This design change should reduce the current frequency of adjustments to maintain proper set point.

- Delete the bi-monthly bubble leak test of the pressure safety valves, and reduce the frequency of the popping-up setpoint test from current once per year to once every 6 years to be more consistent with the ASME recommendations for nuclear Class 2 safety valves.

- Only the Airlock door relays associated with providing the interlock contact pairs should be checked formally to ensure containment integrity. The operation of other relays associated with door operation and testing can be adequately tested during normal operation or testing and necessary corrective maintenance applied in a timely manner.

- Because of the less stringent service conditions for the spent fuel discharge bay containment sealing door (being used only 1-2 times a month), the frequency of its inter-seal leak test should be reduced from once every 4 weeks to once every 13 weeks. Also the frequency of its instrument air leak test should be reduced to once every 52 weeks, consistent with current practice on the Airlocks.

It can be seen from the above recommendations that the maintenance optimization analysis resulted in a significant reduction in the frequency and number of required maintenance operations, leading to an overall reduction cost, while focusing on the maintenance that is critical to the system. For example, it is expected that the recommended program will result in fewer door seal replacements, hence less maintenance effort and also making the airlock itself more available in support of other maintenance activities.

From this analysis work, it was concluded that the methodology was sound. The recommended changes will ensure that the system performance does not deteriorate as the plant enters the second half of it's design life. Needless equipment down time for redundant maintenance will also be minimized.

5.0 Application to Future CANDU Plants

The experience gained performing streamlined RCM studies for existing CANDU stations serves as a solid foundation for defining maintenance strategies for future CANDU nuclear power plants. All the benefits of the streamlined RCM studies are assessed and documented for future plants in CANDU Maintenance Manuals.

Maintenance schedules are specified with condition based maintenance emphasised where practical and effective. System surveillance matrices are also defined. As with the streamlined RCM studies for existing CANDU plants, the basis of all recommendations is provided.

This effort will enable AECL to provide effective guidance to new CANDU utilities on how to effectively maintain their valuable investments. Reactor vendor guidance on maintenance strategies is expected to become strategically more important in future power reactor sale negotiations.

6.0 Conclusions

The application of the streamlined RCM methodology helps to achieve enhanced system reliability and availability, making optimum use of available maintenance resources and provide a documented basis for system maintenance. This approach has been utilised in various industries world-wide and is now being successfully applied to CANDU power plants with the following benefits:

- High capacity plants at reduced cost by focusing maintenance tasks on critical components and only performing preventive maintenance on non-critical components when it is cost effective to do so.
- Better understanding of equipment performance in the current operating context.
- Rationale to demonstrate that maintenance programs are built on a properly analyzed foundation.
- Provides documented basis for gaining regulatory approval of changes.
- Feedback on skills required to maintain the asset.
- Means to optimize the spare parts program.
- Significant cultural change with respect to avoiding or reducing the consequences of failure rather than focusing on eliminating all equipment failures within a system.
- Well documented basis of each maintenance task which will be preserved for future plant personnel responsible for systems and equipment maintenance.
- Results of system studies form a solid foundation from which to define maintenance strategies for future CANDU plants.

Two less tangible benefits of the process are that participants gain a better understanding of how the plants assets work and that they also tend to function better as a team.

References:

(1) J. H. Nickerson, J. R. Hopkins, K. R. Hedges "CANDU Plant Life Management Programs", presented at 1999 SIEN Conference, Bucharest, Romania

(3) J. Moubray, "Reliability-Centered Maintenance, Second Edition", Industrial Press Inc. 1997

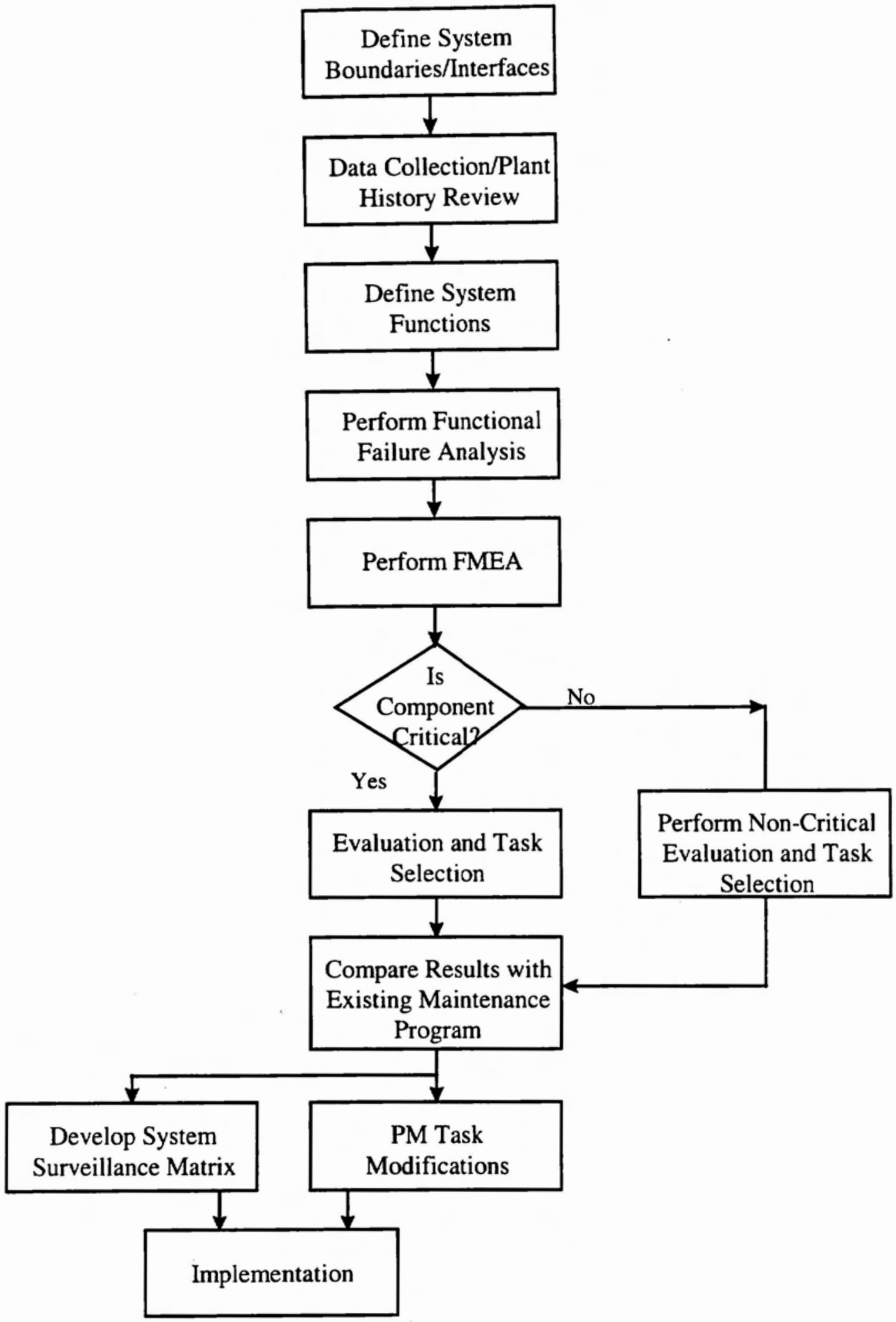

Figure 1 - The Systematic Approach to Maintenance (SAM) Process

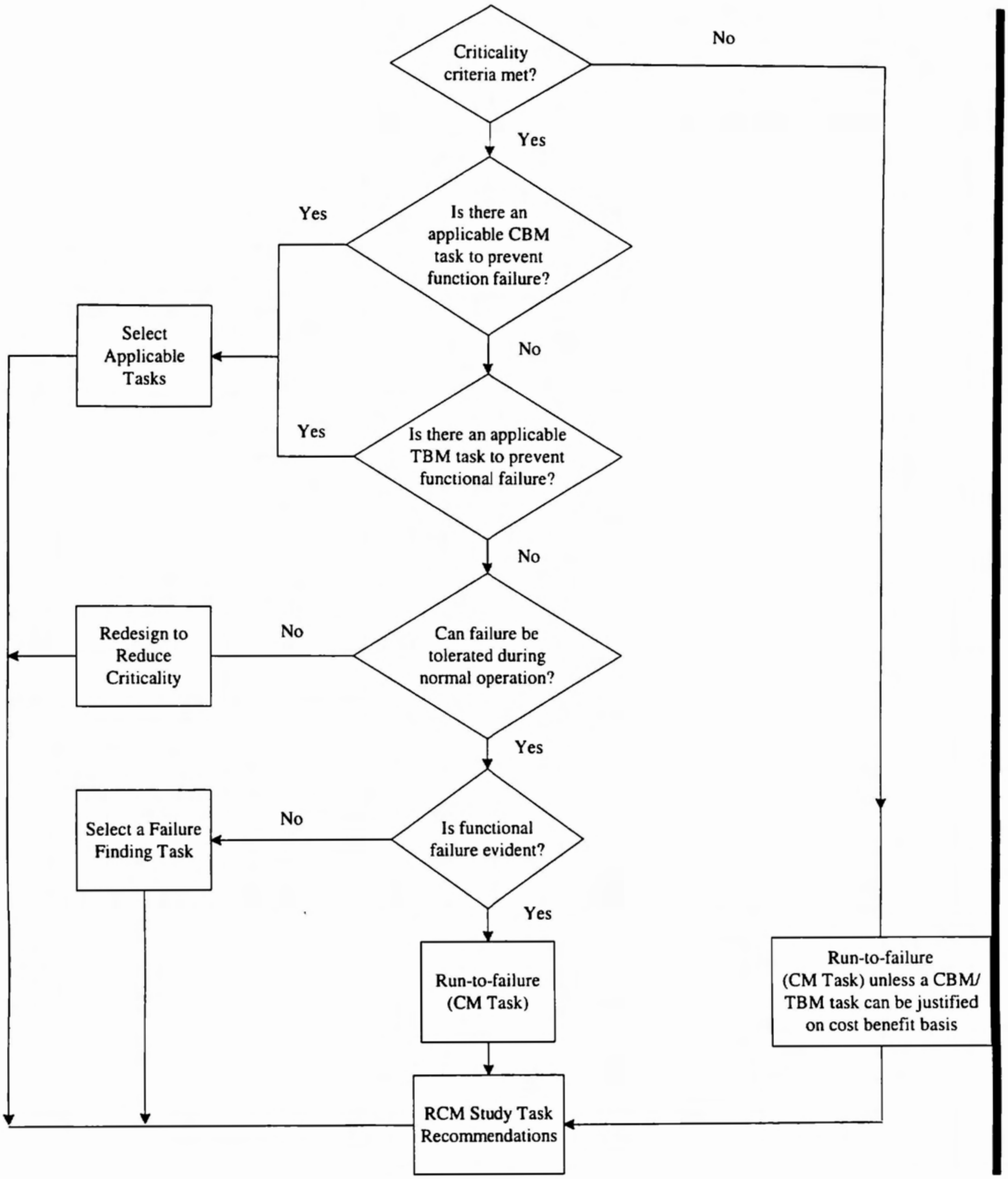

Figure 2 Maintenance Strategy Selection