INTEGRATED MAINTENANCE PROGRAM (IMP)

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ABSTRACT

Approaches to the maintenance of nuclear power plants have undergone significant change in the past several decades. The traditional breakdown approach has been displaced by preventive (calendar-based) maintenance and more recently, by condition-based maintenance (CBM). This is largely driven by the fact that traditional maintenance programs, derived primarily from equipment vendor recommendations, are generally unsuccessful in controlling maintenance costs or equipment failures.

Many advances in the maintenance field have taken place since the maintenance plans for Ontario Hydro's nuclear plants were initially established. Ontario Hydro nuclear plant operating costs can be substantially reduced and Incapability Factor improved with the application of modern maintenance processes and tools. Pickering is designated as the lead station for IMP.

Of immediate concern is the fact that Pickering Nuclear Division has been experiencing a significant backlog of Operating Preventive Maintenance Callups1. This backlog, over 2000, is unacceptable to both station management and the nuclear regulator, the Atomic Energy Control Board. In addition there are over 500 callups in various stages of revision (in hyperspace) without an adequate control nor reporting system to manage their completion. There is also considerable confusion about the classification of "licensing" callups, e.g. callups which are mandatory as a result of legal requirements. Furthermore the ineffectiveness of the Preventive Maintenance (PM) has been the subject of peer audits and Atomic Energy Control Board (AECB) findings over the past several years.

The current preventive maintenance ratio PM2 /(PM+CM3) at Pickering ND is less than 20%, due to the current high load of equipment breakdown. This past summer, an Independent Integrated Performance Assessment (IIPA) review at Ontario Hydro confirmed these concerns.

Over the past several years, Ontario Hydro nuclear staff have evaluated several programs to improve the station's maintenance effectiveness and reduce maintenance costs including RCM4, callup overhauls, analysis of equipment and system failure history to name a few. It has become apparent that there is no single "Do-All" maintenance strategy. What is needed is an integrated program combining the benefits of a variety of problem-specific strategies. Such a program should address both the short term and long term station requirements.

The impact of the Integrated Maintenance Program (IMP) is expected to be high. In the short term, IMP will upgrade the call-up management system to provide accurate classification, effective monitoring and reporting, and develop a documented rationale (PMO) for each Preventive Maintenance task. To the greatest extent possible, IMP will utilize on-condition (predictive) maintenance

and result in the elimination or replacement of many obsolete or ineffective preventive maintenance call-ups. The IMP described in this paper, will improve maintenance effectiveness, equipment reliability and have cost benefits to Ontario Hydro. In doing so it will reduce the cost of maintenance and improve system availability and reliability.

PROGRAM DESCRIPTION

The overall program goal of IMP is to improve the management and effectiveness of the Preventive Maintenance program at OHN (PND as the lead station). The goals of the IMP are to (1) identify "key" or critical systems and components, (2) establish a Condition Based Maintenance (CBM5) program for these systems/components, (3) "optimize" the PM tasks - Preventive Maintenance Optimization (PMO6) for the remaining plant systems/equipment, (4) upgrade the station call-up management system and (4) implement a Preventive Maintenance Living Program (PMLP7) to evaluate the effectiveness of the PM programs and make necessary adjustments during the life of the plant. See attached overview diagram (Figure 1). The IMP is based on a review of best practices in the nuclear power industry as well as the results of two key pilot projects (CBM and PMO) conducted at PND. Visits were made to several US utilities (Duke Power, PECO and PPL) who are highly rated for having effective maintenance programs to review and compare preventive maintenance issues and programs.

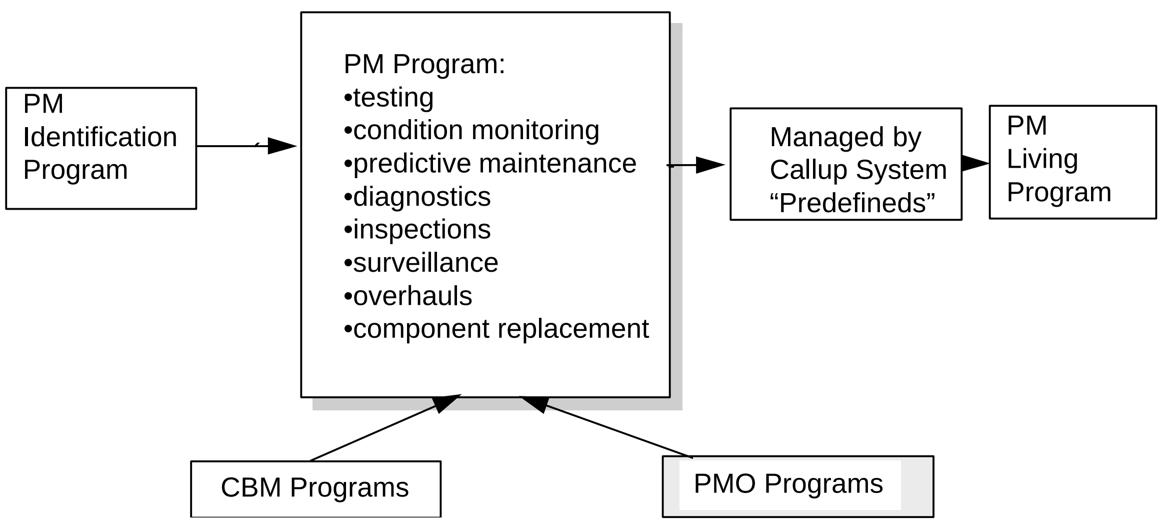

Figure 1 Integrated Maintenance Program Overview

PREVENTIVE MAINTENANCE IDENTIFICATION PROGRAM

There are a number of RCM analysis available to help define PM programs, ranging from the highly analytical classical Failure Modes and Effect Analysis to the expert panel round table method. IMP at PND utilizes a stream-lined RCM process (CBM) for key systems/components and Preventive Maintenance Optimization (PMO) for the balance of the plant. A correct balance must be maintained between economic and safety/risk issues. Typically, it is significantly more expensive to develop a CBM program for a system than to optimize a system's PM program. An effective CBM identifies and trends "equipment performance indicators" and acceptable performance envelops and limits, thereby significantly reducing the risk of unexpected equipment failures. An optimized PM program primarily prescribes a set of time-directed tasks which avoid significant equipment degradation and failure based on statistical and historical data. An important element of IMP is the implementation of a PM identification process to define and select the “key” or critical systems for which a comprehensive CBM program is applied. OHN developed a system ranking criterion which considers safety, production/economic issues and regulatory mandates. Approximately 30 systems qualified for a CBM program and the balance of systems will be analyzed utilizing Preventive Maintenance Optimization. For example the following table (Table 1) identifies the performance indicators of several Pickering systems, the contribution of each system to the station total incapability and its PM ratio (in some cases there is less than 2% PM compared to a desired target ratio of 70%).

Table 1 Proposed Systems for RCM/CBM

	System Name	Scheduled Maintenance Hours	Corrective Maintenance Hours	Operating PM Ratio	Average IcbF(g) by Parent PND-A / PND-B
1	Moderator System Main Circuit *	141	11,073	1.3%	0.13 / 2.62
2	Turbine and Auxiliary Equipment	6,325	24,086	20.8%	1.07 / 1.81
3	PHT Main Circuit* and Feed and Bleed	1,282	21,486	5.6%	1.66 / 1.28
4	Emergency Coolant HP Injection System	485	6,196	7.3%	1.66 / 1.28
5	Feedwater Heaters and Condensate System	1,284	12,778	9.1%	0.82 / 0.47
6	Boiler Feed System	1,539	7,550	16.9%	0.82 / 0.47
7	High Pressure Service Water	718	4,335	14.2%	1.57 / 0.02
8	Standby Generators	2,833	2,674	51.4%	1.05 / 0.51
9	Main Steam Supply System	304	8,978	3.3%	0.08 / 0.45
10	Generator and Auxiliary Systems	2,079	4,725	30.6%	2.11 / 1.47
11	Vapour Recovery System	561	3,308	14.5%	1.57 / 0.02
12	Common Screenhouse Equipment	453	4,429	9.3%	1.57 / 0.02

CONDITION BASED MAINTENANCE PROGRAM

The CBM approach and application was successfully demonstrated with pilot projects in 1996, being applied to the Compressed Air and Low Pressure Service Water systems for PND - B units. These pilots demonstrated that the CBM methodology could be applied effectively to produce more effective and less costly maintenance programs. For example CBM is used to monitor the health of 22 air compressors, determine the residual life of the main components and prescribe appropriate maintenance actions based on the condition of the equipment, vibration levels and oil cleanliness and conditions. In excess of $40k was saved in the first year of operation for this system and a further $140k saved for avoided equipment failures and replacement. The CBM program used at OHN has been adapted from similar programs used in the steel making industry, Dofasco Inc. in particular. CBM is innovative in concept to integrate the appropriate diagnostic technologies to develop a strategy which optimizes the mix among corrective, scheduled and on-condition maintenance. Optimum is defined as maximizing availability and equipment life while minimizing maintenance costs. Subsequently CBM has been applied to eight additional systems in 1997 and will be expanded to an additional 20 systems during 1998-99.

Condition Based Maintenance utilizes a stream-lined RCM process to determine the Failure Mode and Effect Analysis and prescribes maintenance tasks including predictive maintenance techniques based on the observed condition of equipment. This requires defining equipment "condition indicators" which can be measured and quantified. CBM relies on maintaining a historical database of measured conditions, defining the operating limits of the condition indicators and interpretation rules when these limits are exceeded. The following figure (Figure 2) represents the integration of diagnostic technologies and information technology to enable system/equipment surveillance and monitoring.

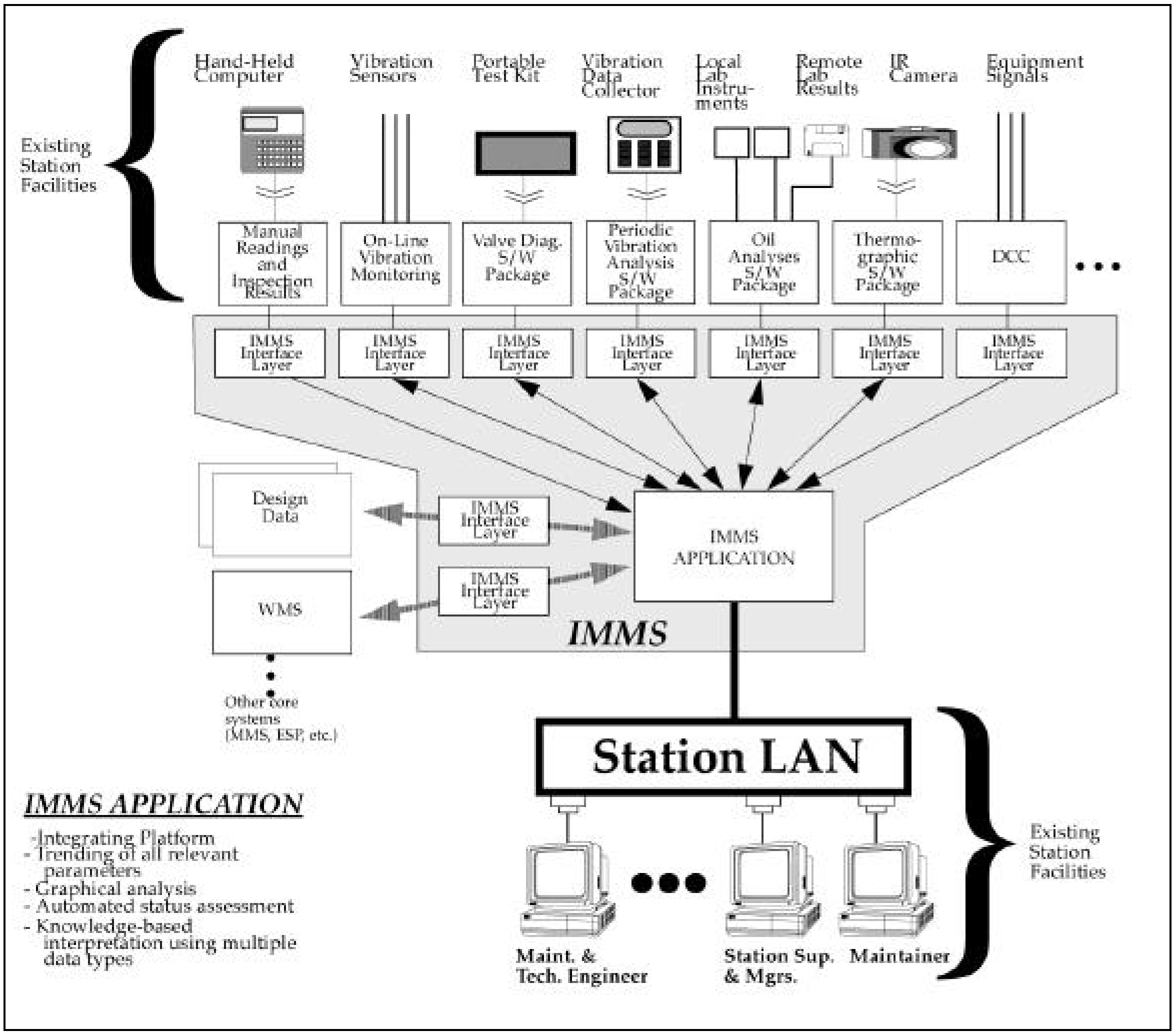

Figure 2

Figure 3 is an example of the data trended for the LP element of a compressor. It should be noted the corrected discharge temperature was one of the condition indicators which was developed during the implementation of CBM. From the data, it can be noted that the temperature has in an alarm range in the fall of 1995. Based on this and other collaborative indicators the compressor elements were replaced and the equipment performance returned to normal in subsequent years.

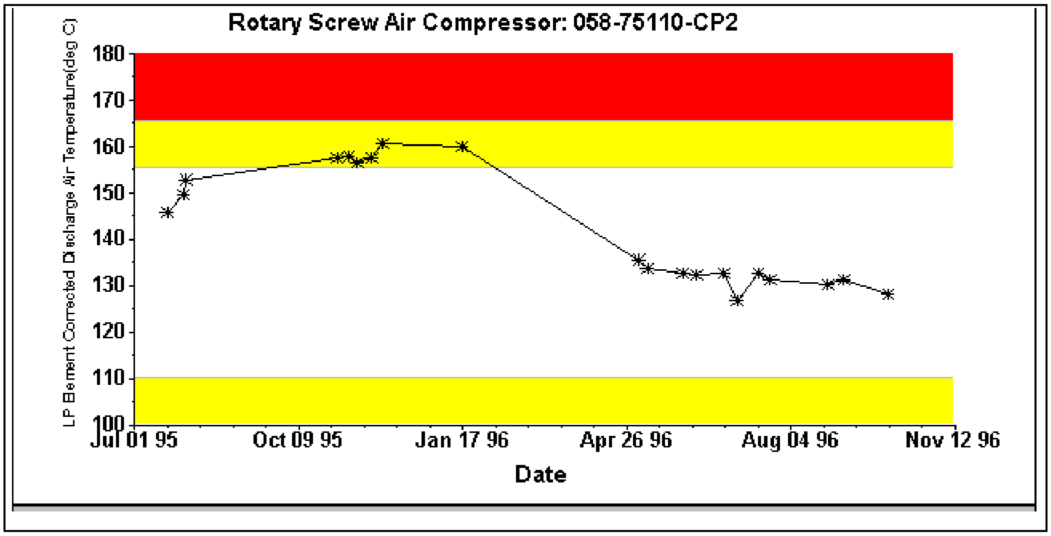

Figure 3

PREVENTIVE MAINTENANCE OPTIMIZATION

The Preventive Maintenance Optimization is a one time program to "challenge/evaluate" the station PM callups and provide a well founded technical basis for each callup. The PMO process recommends deleting obsolete callups and revising/updating the remaining callups as needed. The ultimate goal of the PMO process is to do the right maintenance at the right frequency. PMO strives for the most effective PM callup program possible and to establish a program that adapts as maintenance needs change. These changes may come from regulatory, internal commitments, competitive pressures or age.

PMO utilizes a stream-lined experience-based RCM methodology utilizing Failure Mode Effects and Criticality Analysis (FMECA) to determine the functional significance of component failure modes and Logic Tree Analysis (LTA) to define the most cost-effective and technically applicable form of maintenance to address the dominant failure modes and causes. This process relies on existing data sources and knowledgeable plant staff to alleviate the need to perform a system-level functional analysis as required by traditional RCM approach. In a cost-effective manner, the otimization process addresses all PM concerns including safety, availability, reliability and value. Often, maintenance programs employ redundant tasks and technologies to guard against the same failure. In some cases, this redundancy is necessary for safety, but in other cases it is simply redundant. By optimizing these technologies, a significant cost reduction can be realized. PMO has been conducted at a number of US utilities with excellent results. For example, the implementation of PMO at all three Duke Power Nuclear Stations (7 units) produced the following results in Table 2. Similar proportional results have been found in the pilot work that has been completed to date at Pickering. The objective of the PMO program is to compete the analysis and implement the changes to the current PM program (26,000 callups) over the next two years at Pickering and at all of the OHN plants over the next four years.

Utility	Total PMs	PMs Deleted	PMs Revised	PMs added	PMs Unchanged
Duke	25,826	1,845	6,691	2,173	15,117

Utility	3 Year Savings	St’n Life Savings	Labour Hrs Savings/Year
Duke	$5,721,084	$29,340,017	41,251

PREVENTIVE MAINTENANCE LIVING PROGRAM

The Preventive Maintenance Living Program is based on a process that will ensure continued callup effectiveness. As per Figure 3, the process provides for continuous callup program feedback and reviews through maintaining a technical and business case basis and provides consistency between units and sites. Maintenance effectiveness reviews are conducted monthly or at prescribed intervals to determine system/equipment performance (system health reports).This is a structured process and requires the input from maintenance engineering and operations. For those systems whose performance is not acceptable, based on root cause analysis, decisions are made to modify either the maintenance program, operation of the system or design until performance is acceptable.

BENEFITS

Based on the preliminary pilots in CBM at Pickering and experience from US utilities such as the VC Summer NGS of South Carolina Electric & Gas, Peach Bottom NGS of PECO Energy and Duke Power a conservative estimate of 25k$/system/year savings is attainable. Based on application of the CBM program to 25 systems at 16 units (Pickering units 1-8, Bruce units 1-4 and Darlington units 1-4), this has the potential savings of in excess of 8M$/year of reduced maintenance effort.

Similarly, based on the pilot PMO programs at Pickering and data from implementation of a similar program at the Duke Power nuclear plants, savings associated with eliminating duplicate or ineffective maintenance tasks totaled 5.7M$/year based on a review of 25,000 callups. This project will implement PMO on 16 generating units and a total of 62,000 callups. Therefore, conservatively generating approximately 10M$/year savings.

This represents approximately a savings of 18M$/year. The savings of 18m$/year of manpower allows the maintenance department to execute a significantly greater number of PM callups, thereby improving PM:CM ratio and eliminate CM and PM backlogs.

Improved equipment reliability resulting from the implementation of IMP will result in reduced generating incapability. This positive result has been demonstrated in most US nuclear utilities that have an effective PM program such as Duke Power and PECO. This positive impact however is also dependent on successful implementation of planning, execution and backlog reduction improvement initiatives.

SUMMARY

The Integrated Maintenance Program is being implemented at the OHN stations with Pickering ND as the lead station. IMP addresses the deficiencies identified in a number of audits and reports. The existing PM programs at Pickering have been operating for up to 25 years without the benefit of maintenance process re-engineering. As a result PM callup databases contain many outdated, mis-coded and unapproved callups. Furthermore, limited manpower and resources require that a systematic approach such as the Integrated Maintenance Program be taken to ensure that appropriate level of maintenance programs are developed for critical equipment. IMP will re-establish the technical basis and documentation to perform cost effective PM and provide a process (PMLP) to continue to optimize equipment maintenance and hence performance and availability.

ACKNOWLEDGEMENTS

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REFERENCE

R.T. Zemdegs, F. Fitzsimmons, "Condition Based Maintenance Pilot Projects at Pickering ND", CANDU Maintenance Conference, Toronto, Canada, November 1995.

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1 "Callups are a repetitive maintenance task or inspection or regulatory required test performed on equipment/system to mitigate or identify a particular failure mode/cause or meet legal/regulatory requirements. The recommended callup frequency is defined in terms of weekly intervals with a lead/late time for completion.

2 Preventive Maintenance (PM) is work done to prevent or reduce the likelihood of equipment failure. It includes predictive, periodic maintenance and inspection.

3 Corrective Maintenance (CM) refers to maintenance carried out due to an unplanned equipment failure. The preventive maintenance ratio is the ratio of the total hours spent on preventive maintenance versus the total maintenance hours consisting of the sum spent on preventive maintenance tasks and the corrective unplanned maintenance hours. A ratio of about 70% is desirable.

4 The Reliability Centered Maintenance (RCM) methodology provides the procedures and decision logic for guiding the identification of maintenance requirements. RCM analysis considers the operational consequences of each equipment failure mode in arriving at an optimized maintenance plan.

5 Condition Based Maintenance (CBM) is a process whereby equipment condition is ascertained through the periodic measurement and trending of equipment condition indicators. Condition indicators are typically calculated from a number of measured physical parameters, e.g. pressure, temperature, vibration level, oil analysis, etc…

6 The PMO program is an analysis technique to determine the relevant failure modes and effects of plant equipment, identify dominant causes and prescribe appropriate PM tasks.

7 A Preventive Maintenance Living Program (PMLP) maintains the PM call-ups following an initial PMO or CBM process. The PMLP process allows for continuous improvement to the technical basis for call-ups and incorporates new techniques and processes that further optimize the cost benefits of the call-up process and programs.