PM OPTIMISATION

Using PMO2000™ Reliability Software and Methodology

A Tool for Improving Operations and Maintenance in the 21st Century

Information package
for organisations
with assets currently in use

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Introduction

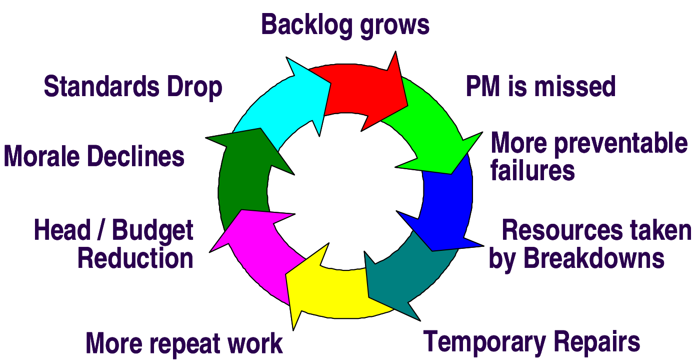
Maintenance is often the largest controllable operating cost in manufacturing, utilities, heavy processing and mining industries. It is also a critical business function that impacts on plant output, product quality, production cost, safety and environmental performance. For these reasons maintenance is regarded in best practice organisations not simply as a cost to be avoided but, together with reliability engineering, as a high leverage business function. It is considered a valuable business partner contributing to asset capability and continuous improvement in profitability.

The Reactive Maintenance Spiral

Many maintenance organisations face an excessive level of reactive or breakdown maintenance. This is expensive in terms of both maintenance cost and downtime consequences.

Excessive reactive maintenance also contributes to a negative performance spiral that at best counters other valuable improvement initiatives and, in the worst case, leads to an almost completely reactive environment. This can be explained very simply.

The Vicious Cycle of Reactive Maintenance



When breakdowns occur unexpectedly, resources are deployed to reactive work at the expense of Preventive Maintenance (PM). PM is missed due to scarce resources being consumed by breakdowns. As PM is missed, more preventable failures occur expanding the level of reactive maintenance. In many cases, the situation is compounded by band-aid maintenance, and morale adversely affected by long working hours under high pressure and continual fire fighting.

Reversing the Reactive Maintenance Spiral

The Options

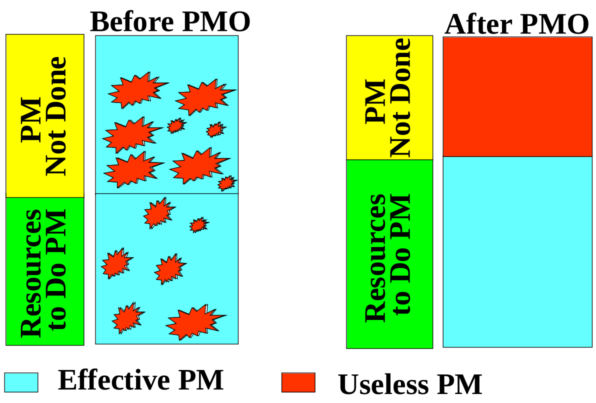
A challenge for many companies is to move out of a reactive maintenance cycle. Intuitively, the answer lies mostly in the ability of an organisation to obtain more labour resources or gain better access to the assets for maintenance. Most commonly, the option of increasing labour resources is not available and asset maintenance periods are constrained by factors external to the maintenance department. The only option therefore is to increase the productivity or effectiveness of existing personnel and make better use of the time allocated to maintenance.

The truism that "*unless things are done differently, the past will continue"* has never had a greater place than in organisations caught in a reactive maintenance spiral.

THE SOLUTION

In 1996 Strategic Industry Research Foundation[1] (SIRF), responded to industry concerns that whilst RCM was a useful analysis tool, it did not suit the needs of organisations that had existing maintenance programs and could not afford to start all over again. SIRF recognised that the fundamental problem with RCM was that it is a tool designed for use in the design phase of the asset life cycle and not once the asset has been in use. Consequently it contains steps that add little or no value to the objectives of the analysis. Conversely, PMO is a tool specifically designed to review the maintenance requirements, failure history and technical documentation for assets that are in use. PMO had been applied in the North American Nuclear Industry when it had faced goals of increased asset performance, increased environmental and safety targets, and reduced maintenance costs. PMO has received credit from the North American Nuclear Power industry regulator as a Major Strength based on work completed in a number of plants.

Over the past six years, an approach suitable for industries outside of Nuclear Power has been developed by OMCS. This program is known as PMO2000™.



Over the five years of development a startling outcome of the initial programs was that, almost without exception, the companies involved found the following weaknesses in their maintenance strategies:

- Many PM tasks duplicated other tasks.
- Some PM tasks were done too often.
- Some PM tasks were done too late.
- Some PM tasks serve no purpose whatsoever.
- Many tasks were intrusive and overhaul based whereas they would be far more effective, less costly and in harmony with production needs if they were condition based.
- Some condition-based inspections were overly intrusive and there was sufficient failure data available to set a safe life and eliminate the frequent stoppages for inspection.
- Some condition-based tasks could be far more effective and efficient if modern diagnostic tools were used.

In almost every environment, a significant amount of misdirected maintenance labour was found. In some areas it was found that no more than 13% of the PM being done was properly focussed. Obviously, this low level of PM effectiveness contributed massively to poor maintenance labour productivity and low availability of the plant.

[1] *In June 2000, State Government funding was removed from SIRF. Maintenance activities conducted by SIRF were adopted by SIRFrt (refer to www.sirfrt.com.au) under government grants.*

In addition, most organisations were surprised to find that a significant part of their maintenance strategies were done informally or outside of a controlled system and therefore difficult to plan, organise and control.

PM Optimisation programs now continue in hundreds of Companies in around the world in manufacturing, mining, mineral processing, utilities and oil and gas sectors. Enterprise level software is now available for sale as is a variety of implementation approaches, and a range of training programs. PM Optimisation has become a key element of some of the improvement programs in mining and oil and gas multinationals.

PMO2000™ from A to Z.

OVERVIEW

The PMO2000™ process has nine steps. These steps are listed below and discussed in the following pages.

Step 1 Task Compilation

Step 2 Failure Mode Analysis

Step 3 Rationalisation and FMA Review

Step 4 Functional Analysis (Optional)

Step 5 Consequence Evaluation

Step 6 Maintenance Policy Determination

Step 7 Grouping and Review

Step 8 Approval and Implementation

Step 9 Living Program

PROJECT RANKING

It should be noted that a full PMO2000™ assignment, there needs to be some form of criticality or system ranking process. This may be done by reviewing the equipment hierarchy, and subdivide it into appropriate systems and/or equipment items for analysis. Having performed this task, the criticality of each of the equipment items/systems identified is assessed in terms of their contribution to the client organisation's strategic objectives. Higher criticality systems tend to be those that will have an impact in the following ways:

- Have a high perceived risk in terms of achieving safety or environmental objectives,
- Have a significant impact on plant throughput, operating or maintenance costs, or
- Are consuming excessive labour to operate and maintain.

Having conducted the criticality assessment, this is used as the basis for assessing which equipment items or systems should be analysed first, and the overall level of rigour required for each analysis.

STEP 1- TASK COMPILATION

PM Optimisation starts by collecting or documenting the existing maintenance program (formal or informal) and loading it into a database via a spreadsheet. It is important to realise that maintenance is performed by a wide cross section of people including operators. It is also important to realise that in many organisations, most of the Preventive Maintenance program is done by the initiative of the tradesmen or operators and not documented formally. In this situation, task compilation is a simple matter of writing down what the people are doing. It is common for organisations to have an informal PM system in operation whilst it is rare for an organisation to have no PM at all.

Figure 1 - Sources of Preventive Maintenance

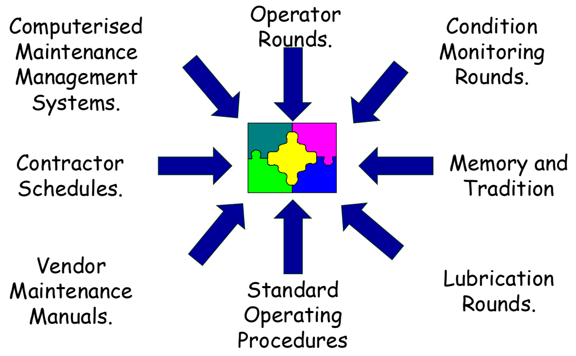


Figure 1 illustrates the sources of PM programs.

STEP 2 - FAILURE MODE ANALYSIS

Step 2 involves people from the shop floor working in cross-functional teams identifying what failure mode(s) each maintenance task (or inspection) is meant to address. Figure 2 illustrates the output of Step 2.

Task	Interval	Trade	Failure
Task 1	Daily	Operator	Failure A
Task 2	Daily	Operator	Failure B
Task 3	6 Months	Fitter	Failure C
Task 4	6 Months	Fitter	Failure A
Task 5	Annual	Electrician	Failure B
Task 6	Weekly	Operator	Failure C

Figure 2 - Illustration of Step 2

STEP 3 - RATIONALISATION AND FAILURE MODE REVIEW

Through grouping the data by failure mode, task duplication can be easily identified. Task duplication is where the same failure mode is managed by PM conducted by more than one section, and is most commonly found between operators and trades, and trades and condition monitoring specialists. In this step, the team reviews the failure modes generated through the Failure Mode Analysis and adds missing failures to the list. The list of missing failures is generated through an analysis of failure history, technical documentation (usually P&IDs) or the experience of the team. Figure 3 illustrates the output of Step 3. Note the addition of a new failure cause "D" that has been identified during this step.

Task	Trade	Cause
Task 1	Operator	Failure A
Task 4	Fitter	Failure A
Task 7	Greaser	Failure A
Task 2	Operator	Failure B
Task 5	Electrician	Failure B
Task 3	Fitter	Failure C
Task 6	Operator	Failure C
		Failure D

Figure 3 - Illustration of Step 3

STEP 4 - FUNCTIONAL ANALYSIS

The functions lost due to each failure mode can be established in this step. This task is optional, and may be justified for analyses on highly critical or very complex equipment items, where sound understanding of all the equipment functions is an essential part of ensuring a comprehensive maintenance program. For less critical items, or simple systems, identifying all of the functions of an equipment item adds cost and time, but yields no benefits. Figure 4 illustrates Step 4.

Step 5 - Consequence Evaluation

In Step 5, each failure mode is analysed to determine whether or not the failure is hidden or evident. For evident failures a further determination of hazard or operational consequence is made. Figure 5 illustrates Step 5.

Task	Trade	Cause	Function
Task 1	Operator	Failure A	Function 1
Task 4	Fitter	Failure A	
Task 7	Greaser	Failure A	
Task 2	Operator	Failure B	Function 1
Task 5	Electrician	Failure B	
Task 3	Fitter	Failure C	Function 2
Task 6	Operator	Failure C	
		Failure D	Function 1

Figure 4 - Illustration of Step 4

Step 6 - Maintenance Policy Determination

Modern maintenance philosophy stems from the premise that successful maintenance programs have more to do with the consequences of failures than the asset itself.

Task	Trade	Cause	Function	Effect
Task 1	Operator	Failure A	Function 1	Operation
Task 4	Fitter	Failure A		
Task 7	Greaser	Failure A		
Task 2	Operator	Failure B	Function 1	Operation
Task 5	Electrician	Failure B		
Task 3	Fitter	Failure C	Function 2	Hidden
Task 6	Operator	Failure C		
		Failure D	Function 1	Operation

Figure 5 Illustration of Step 5

In this step, each failure mode is analysed using Reliability Centred Maintenance (RCM) principles. This step establishes new or revised maintenance policies. During this step the following become evident:

- The elements of the current maintenance program that are cost effective, and those that are not (and need to be eliminated),
- What tasks would be more effective and less costly if they were condition based rather than overhaul based,

Cause	Function	Effect	Policy	Interval
Failure A	Function 1	Operation	Inspect	Daily
Failure B	Function 1	Operation	No PM	
Failure C	Function 2	Hidden	Test	Annually
Failure D	Function 1	Operation	Inspect	Weekly

Figure 6 Illustration of Step 6

- What tasks serve no purpose and need to be removed from the program,
- What tasks would be more effective if they were done at different frequencies,
- What failures would be better managed by using simpler or more advanced technology,
- What data should be collected to be able to predict equipment life more accurately, and
- What defects should be eliminated by root cause analysis.

Figure 6 illustrates Step 6.

STEP 7 - GROUPING AND REVIEW

Once task analysis has been completed, the team establishes the most efficient and effective method for managing the maintenance of the asset given local production factors and other constraints. In this step it is likely that tasks will be transferred between trades and operations people for efficiency and productivity gains.

STEP 8 - APPROVAL AND IMPLEMENTATION

In Step 8, the analysis is communicated to local stakeholders for review and comment. The group often does this via a presentation and an automatic report generated from the PM Optimisation software. This software details all the changes and the justification for each.

Following approval, the most important aspect of PMO2000™ then commences with implementation. Implementation is the step that is most time consuming and most likely to face difficulties. Strong leadership and attention to detail are required to be successful in this step.

The difficulty of this step increases markedly with more shifts and also with organisations that have not experienced much change

STEP9 - LIVING PROGRAM

Through Steps 1 to 9, the PM Optimisation process has established a framework of rational and cost effective PM. In the "Living Program", the PM program is consolidated and the plant is brought under control. This occurs as reactive maintenance is replaced by planned maintenance. From this point improvement can be easily accelerated as resources are freed to focus on plant design defects or inherent operational limitations.

During this step, several vital processes for the efficient management of assets can be devised or fine tuned as the rate of improvement accelerates.

These processes include the following:

- Production / maintenance strategy,
- Performance measurement,
- Failure history reporting and defect elimination,
- Planning and scheduling,
- Spares assessing, and
- Workshop and maintenance practices.

In this step it is the intention to create an organisation that constantly seeks to improve its methods by continued appraisal of every task it undertakes and every unplanned failure that occurs. To achieve this requires a program where the workforce is adequately trained in analysis techniques and is encouraged to change practices to improve their own job satisfaction and to reduce the unit cost of production.

Deciding when to use RCM and when to use PMO.

There is no doubt that conventional and statistical approaches to RCM have assisted industry gain better control of their assets and manage them more intelligently. However, it has long been considered that both methods have weaknesses and have not lived up to expectations.

REVIEW OF THE RCM APPROACH

According to the standard SAEJA1011 Issued Aug 1999, any RCM program should ensure that all of the following seven questions are answered satisfactorily and are answered in the sequence shown:

1. What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?
2. In what ways can it fail to fulfil its functions (functional failures)?
3. What causes each functional failure (failure modes)?
4. What happens when each failure occurs (failure effects)?
5. In what way dose each failure matter (failure consequences)?
6. What should be done to predict or prevent each failure (proactive tasks and task intervals)?
7. What should be done if a suitable proactive task cannot be found (default actions)?

FUNCTIONAL DIFFERENCES

RCM and PMO2000™ are both methods used to define the complete maintenance requirements of physical assets.

Nowlan and Heap (1978) coined the term Reliability Centred Maintenance (RCM) as a process to be used to draw up maintenance programs for new types of aircraft *before* they entered service (Moubray, 1997). Thus it was a zero-based tool developed for use in the design phase of an asset's life cycle.

In the absence of better methods, since Nowlan and Heap, RCM has been applied retrospectively to plants well into their life cycle. In over 20 years since its derivation, RCM has failed to become a day to day activity performed by most organisations. Few organisations have applied RCM to anything other than their most critical assets suggesting that there need to be alternate paths to the creation of maintenance policies rather than starting from scratch.

In response to this need, PMO2000™ was developed as a process of review for assets that have an established maintenance program (formal or informal) but where that maintenance program was inefficient or misaligned with business needs.

METHODOLOGY DIFFERENCES

The central difference between RCM and PMO2000™ is the way in which failure modes are generated.

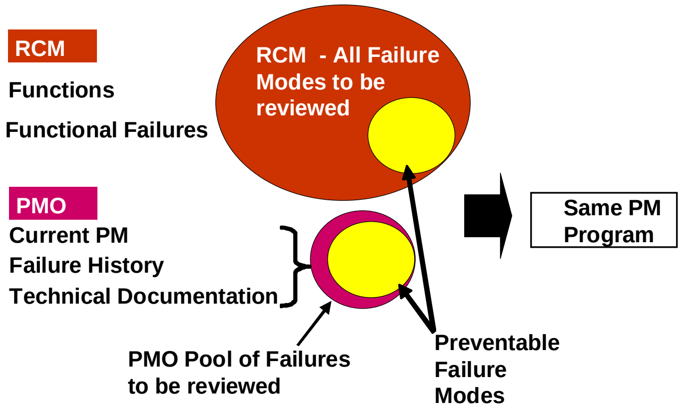


Figure 7 Illustration of how RCM and PMO produce the same result.

- RCM seeks to analyse every failure mode on every piece of equipment within the system being analysed.
- PMO generates a list of failure modes from the current maintenance program, an assessment of known failures and by hazard analysis of technical documentation - primarily Piping and Instrumentation Diagrams (P&IDs).

The differences in the two approaches mean that PMO2000™ deals with significantly less failure modes than RCM and arrives at the failure modes in a far quicker time frame. PMO2000™ selective coverage means that the maintenance program that results will be the same regardless of whether PMO2000™ or RCM is used (figure 7).

Other differences are discussed in the following paragraphs.

1. FAILURE MODE ANALYSIS

The focus of good equipment design is to ensure high levels of reliability, maintainability and operability over the equipment life cycle. At the design stage, this means attempting to eliminate all high likelihood and high consequence failures

It is therefore, not surprising that when reviewing the complete set of likely failure modes using RCM analysis, that by far the greatest number of outcomes, or recommendations, are "No Scheduled Maintenance". This is to say that for the failure modes left in the design, either:

- Their likelihood is very low therefore the cost of a preventive or predictive task is likely to be more than the cost of failure, or
- There is no technically feasible predictive or preventive maintenance task known to manage them.

In the author's experience, rigorous RCM analysis of equipment in accordance with the standard shows that, on average, about 80% of failure modes result with the policy of No Scheduled Maintenance.

This number rises with electronic equipment such as a PLC and falls with equipment that has a high number of moving parts such as a conveyor

2. ROLLING UP OF FAILURE MODE ANALYSIS WHERE LOGICAL

RCM treats each failure mode independently. This results in the same analysis being documented many times but resulting in only one task being recommended for all the failure modes listed. Using RCM this is unavoidable no matter how experienced the analysis team may be.

Task	Failure mode analysed (rolled up)
Perform Vibration Analysis on the Gearbox	Gear wears, or cracks. Gear bearing fails due to wear. Gearbox mounting bolts come loose due to vibration. Gearbox coupling fails due to wear.

Table 1. Illustration of Failure Mode Analysis using PMO

Function	Functional Failure	Failure modes
To provide 20 hp of power to the fan such that the fan spins at 200 rpm.	No power whatsoever	Gear wears.
	No power whatsoever	Gear cracks due to fatigue.
	No power whatsoever	Coupling fails due to wear.
	No power whatsoever	Gearbox bearings fail due to wear.

Table 2. Illustration of Failure Mode Analysis using RCM

PMO2000™ starts from the maintenance task and therefore many failure modes can be listed against the one task. This significantly reduces the analysis time by reducing the records that need to be dealt with. The concept can be best described by reference to Tables 1 and 2.

It can be seen from Table 1 that providing vibration analysis was a technically feasible and cost effective task to prevent all these failure modes from occurring unexpectedly, PMO2000™ would consider the failure modes as a group.

Conversely at Table 2, RCM can be seen to have created a lengthy analysis process compared with PMO2000™. Accepting that the resulting maintenance program will be the same the route to this result covered four times the administration and probably double the analysis time. Furthermore, with decomposed failure modes, there is additional administrative effort required to roll them back up and link the four failure modes to the one task.

3. Optional Functional Analysis

RCM begins with a complete functional analysis of the equipment whereas with PMO the effort expended on functional analysis is discretionary. This is primarily because consequence evaluation is performed at Question 5 of PMO2000™. As consequence evaluation implicitly involves understanding what loss of function is incurred, additional functional assessment is a duplication[2] of effort.

Done properly, functional analysis consumes 30% of the total RCM analysis time and is the lowest value adding activity of the process.

Flexibility Comparisons

Filtering of Failure Modes by Trade

RCM analysis cannot regulate or filter which failure modes are analysed at which time. Therefore, RCM analysis requires the presence of all trades simultaneously. With PMO2000™ it is possible to review the activities of a particular trade on a particular piece of equipment or site. This is because PMO2000™ begins with maintenance tasks that can be filtered by trade. This is particularly useful when the activities of one trade are ineffective or inefficient and need to be reviewed in isolation from other trades.

There have been highly successful PMO2000™ analyses performed exclusively on

[2] *This point is also relevant where functions are hidden, as the loss of hidden functions will result in consequences that are conditional on some other failure occurring.*

either operator rounds, on instrumentation rounds, on lubrication rounds, on vibration analysis rounds etc. This type of focus is not possible using RCM.

PMO IS SELF REGULATING IN TERMS OF INVESTMENT AND RETURN

PMO2000™ is highly effective where equipment has numerous failure modes but where the vast majority of these are either random, instantaneous or not of high consequence. A simple example would be a mobile telephone. Mobile phones have hundreds of functions. To define the functions of a mobile phone would take many hours depending on how rigorous the group was in defining performance standards.

The other point here is that RCM if done diligently would require the input of specialist electronics engineers to define the failure modes properly[3]. Conversely, PMO2000™ would require only the operators as electronic failure modes would not form part of the pool of failure modes that are currently addressed by PM nor part of the failure history to any great extent.

PMO2000™ would take no more that 20 minutes to complete the analysis in total and realise that the only maintenance that is required is to do with managing the consequences of battery deterioration

BENEFITS OF SPEED

Experience in the US Nuclear Power Industry was that over a large number of analyses, PMO2000™ was on average six times faster than RCM (Johnson, 1995). PMO2000™ is considered to be a much faster approach than the approach taken by Johnson.

The positive effect of deploying a process of maintenance analysis that is six times faster than RCM for the same given outcome cannot be overstated. The benefits are listed below:

- Resources to perform analysis are generally the most valuable and scarce on site. The less resource intensive the program (for the same results) the less the organisation will suffer from the loss of its most valuable people.
- Efficient analysis allows the organisation to be implementation intensive rather than analysis intensive.
- Maintenance analysis is subject to diminishing returns. PMO2000™ is cost effective on all items of the plant whereas it is difficult to justify RCM on any other than critical assets because of the high fixed cost and the inflexibility of the process.
- Where the maintenance of failure modes that have safety or environmental consequences is considered suspect, the use of PMO2000™ will allow these issues to be dealt with much faster than by using RCM as they will be eradicated plant wide six times faster.
- First line supervisors who invest in the program get rewarded with labour productivity improvements six times greater. PMO2000™ targets a return on analysis time of 5 to 1. That is for every man-hour invested in analysis, five man-hours will be returned to the department every year. At this rate, line supervision is prepared to invest their resources. At a rate six times less, they often become uncooperative.

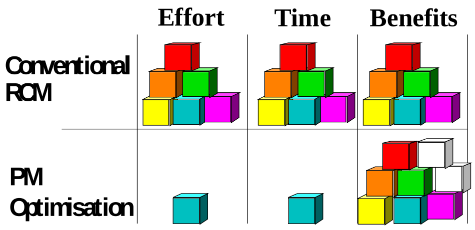
[3] *In fact what happens in reality is that RCM facilitators "Black Box" the item which is to say that RCM in its strict use can not cope efficiently with analysis of such assets.*

WEAKNESSES OF STATISTICALLY BASED METHODS

Many organisations that have tried statistical methods have found that the outputs are frequently poor and misdirected due to the guesswork needed to compensate for a lack of data and other subjective production and accounting inputs. They also tend to ignore the valuable contribution to condition monitoring made by the operators.

Another drawback found in the use of statistical packages is the low involvement of shop floor personnel. This leads to omissions in the analysis.

PM Optimisation is six times faster than Conventional RCM for existing plant.



The overall results of an incomplete or misdirected program are problems with implementation with the shop floor personnel failing to embrace the schedules.

By contrast, PMO2000™ decision diagram conforms to SAE JA1011, Issue Aug1999. This means that analysis is more experiential and empirical than purely statistical methods. PMO2000™ therefore relies heavily on the knowledge of the shop floor personnel and their understanding of the data. This creates a high degree of ownership and a direct responsibility to make maintenance work.

In final contrast, many statistical methods use algorithms that are based on flawed assumptions and do not conform to SAE JA1011 even though their name suggests they do[4]. This amplifies the errors caused by poor data and can result in serious levels of reactive maintenance of over expenditure.

Key Features of a PM Optimisation Program

PMO QUICKLY FORMS THE BASELINE FOR EFFECTIVE RELIABILITY ENGINEERING AND DEFECT ELIMINATION

There are two important points that allow effective reliability engineering and defect elimination. These are discussed below:

1. The first is bringing the plant failures from unexpected events to controlled corrective action.

In many organisations, reliability problems are seen mostly as problems with design or production methods. Experience tells us that the majority of reliability problems experienced by plants that are overly reactive, is a result of lack of maintenance or care rather than the design. Before expensive redesign is considered, organisations need to ensure that appropriate maintenance is being performed and then decide if the equipment is fit for purpose rather than assuming that the maintenance is adequate and the problem must be a design issue. The fundamental strength of a PMO2000™ program is that all maintenance tasks add value so there it makes good business sense to complete 100% of the program. Through the program a move reducing breakdown maintenance creates productivity improvements that clear the path to allow this to occur. After a short while, failures caused by lack of maintenance are rare.

[4] *Readers interested in learning more about where these algorithms are flawed can contact the author.*

The second is having a system where all the maintenance strategies (including operator rounds, condition monitoring rounds lube rounds, contractor PM etc) are stored in the one place and stored in such a way that each strategy or task is linked to a specific or set of failure modes.

In most, if not all Computerised Maintenance Management Systems (CMMS), there is no link between the equipment, its failure modes and the maintenance strategy. As much of the maintenance strategy is stored outside of the CMMS, the effort required to first assess if an unexpected failure was a result of lack of maintenance is a very time consuming and often a "hit and miss" affair. PMO allows for quick and efficient reference to the equipment failure modes and the current strategy. Moreover, in the living program, PMO2000™ software allows for an efficient and controlled means of changing the strategy.

PM Optimisation is based on Sound Engineering Principles.

PM Optimisation utilises the RCM principles and concepts that have been successfully applied in the airline industry for over 30 years and in other industries for nearly 20 years. These principles have successfully improved operational reliability of civil aviation aircraft by over 10,000% during this time. Whilst PMO2000™ utilises the RCM principles, the implementation approach that is utilised by the airlines and other providers of "classic" RCM consultants has serious practical weaknesses in an industrial environment, as discussed earlier. PMO2000™ applies the RCM principles and concepts in a manner that is more highly focused on benefits realisation in an industrial environment than traditional RCM approaches.

PM Optimisation Recognises And resolves Problems with Data Accuracy.

While PMO2000™ utilises existing failure history as one input to the PM review, it also recognises that in most organisations today, the data that is contained in CMMS systems is likely to be inaccurate and incomplete. Frequently, one benefit that arises from using in-house personnel in this way is a significantly increased recognition, amongst shopfloor people, of the need for accurate data recording on Maintenance work orders. When successfully harnessed, this can drive significant cultural change towards increased data accuracy and a focus on "management by the facts".

PM Optimisation Makes Effective Use of Scarce Labour Resources.

In these days of "lean" organisations, any improvement effort that requires the involvement of in-house labour, whether from the shopfloor, or support staff, must be sure to use these labour resources in a highly productive and effective manner.

Unlike other approaches, PMO2000™ is strongly productivity focussed. PMO2000™ makes best use of the involvement of shopfloor personnel by:

- Having an analyst collect and consolidate existing failure data prior to review by shopfloor work teams,
- Focusing effort on those failure modes which are currently causing problems, or which are currently subject to some form of PM. In classic RCM analysis, more than 50% of failure modes that are analysed result in No Scheduled Maintenance. PMO2000™ reduces the time and effort wasted on these failure modes.
- Taking a more targeted approach to the development of equipment function statements than classical RCM (and in many cases, eliminating the need for function statement definition at all).

In effect, PM Optimisation rationalises what is being done, and adds to that what needs be done that wasn't in place previously. In doing this, PMO2000™ can be six times faster at analysis than conventional RCM, thus shifting the resource intensity from analysis to implementation.

PM Optimisation Improves the Productivity of Operators and Maintainers

Not only does PMO2000 make most effective use of operators and maintainers time during the course of the PMO analysis, it also significantly improves the productivity of operators and maintainers during the course of their daily duties. It achieves this in two ways.

First, PMO2000™ successfully identifies areas where there is overlap between operators', maintainers' and contractors' duties, and effectively resolves any duplication or communication issues involved. For example,

- Vibration Analysis contractors may be being used to monitor bearing vibration on certain pumps on site.
- Operators may be being required to monitor these same bearings for audible noise during the course of their daily rounds, and
- Tradesmen may be expected to replace these bearings on a routine basis during scheduled pump overhauls.

In this case, PMO2000™ would rationalise this situation by resolving the conflicting maintenance strategies in place for the bearings (condition-based vs scheduled replacement), and by resolving the duplicate inspections being performed by both contractors and operators. In most organisations, where PM programs have grown in an informal manner in response to specific situations and events, our experience has been that there is significant duplication of this type.

Second, PMO2000™ ensures that the person with the appropriate skills to perform a specific task is the one that is allocated that task. In most organisations, skilled tradespeople are being utilised to perform routine visual inspections that require no specialist trade skills. On the other hand, operators are already working in the area, and have the necessary skills, and time, to perform these inspections. In the team-oriented forum of the PMO review meetings, we frequently find that operators volunteer to take on these additional duties, and tradespeople are happy for the operators to perform them. This releases tradespeople's time to perform work that better utilises their specialist skills, and which they find more interesting. The result is a general up-skilling of the trades workforce, with a focus on performing higher quality, precision maintenance.

PM Optimisation Is Adaptable to Suit Specific Client Situations and Objectives

A major feature of the PMO2000™ process is the ability of the technique to be applied with various levels of rigour whether the system depending on the criticality assessment. This contrasts with other approaches, which apply the same level of rigour (and time, effort and expense) to the analysis of all systems, regardless of their criticality and regardless of the size of the benefits to be obtained from the analysis. For highly critical equipment items, where a more "classic" RCM approach is required, including identification of all equipment functions, consideration and analysis of all possible failure modes, and where compliance with International Standards for RCM Analyses are required, PMO2000™ will apply this level of rigour. Even in these situations, however, the nature of the PMO200 0 process means that these rigorous analyses are still completed more quickly than "classic" RCM processes. For less critical items, where the time and effort involved in a high level of rigour cannot be justified, PMO2000™ takes a more streamlined and focused approach. In this way, PMO2000™ is highly focused on maximising the return for effort involved in reviewing routine operations and maintenance tasks.

PM Optimisation Motivates Personnel

PMO2000™ quickly revitalises the motivation of the people working within the process of maintenance. In doing so, performing the analysis can result in step improvements in both human resource and plant productivity. The PMO2000™ approach also motivates improvements in many other aspects of asset management apart from the maintenance analysis: Some of these areas are:

- Production / Maintenance Strategy,
- Performance measurement,
- Failure history recording,
- Defect elimination,
- Work order management, and
- Spares management.

Implementing PMO2000™

A full scale PMO2000™ implementation program generally starts with some workshops or briefings introducing key decision-makers to the process. The objective of these sessions is to lay the groundwork for ensuring successful implementation.

Prior to this however, most organisations choose to trial the PMO2000™ process on one or more equipment items or systems. In this environment, the workshop is strongly facilitator lead. Following the trial, the benefits, costs and implementation issues are assessed, and a decision reached on whether, and how, to roll out PMO2000™ on a wider scale within the organisation. Following a trial, the take up rate has been 100%.

Three implementation options are available, as outlined below.

Option 1 - PMO2000™ Consultant provides full time project management, training and facilitation

This approach is suitable for companies in the following situation:

- Limited internal management resources to drive the program,
- Poor asset management systems and documentation,
- Large opportunity to improve uptime and this opportunity translates to significant increases in profitability.
- Moderate or poor record of implementing new systems and modern management philosophies.

Option 2 - PMO2000™ Consultant provides part time training, workshop facilitation and limited project support

This approach is suitable for companies in the following situation:

- Can dedicate one full time resource to the project.
- Good standard of asset management systems and procedures.
- Isolated areas of opportunity to improve and moderate impact on profitability.
- Good record of successfully implementing new systems and modern management philosophies.

Option 3 - PMO2000™ Consultant provides Training only

This approach is suitable for companies in the following situation:

- Can dedicate a team of specialist tradesmen and engineers to the project full time. This usually applies to sites that have a full time reliability group or section.
- Advanced asset management systems.
- Deriving profitability through advanced reliability engineering practices.
- "Implementing change" is a way of life.

Introduction to PMO2000™ - Reliability Improvement Software

GENERAL DESCRIPTION

PMO2000™ is a Windows based industrial maintenance and failure analysis tool designed for the following:

- Defining plant maintenance requirements, and
- Performing reliability growth programs.

Whereas today's Computerised Maintenance Management Systems (CMMS) are excellent administrators, PMO2000™ provides the expert information system, analysis logic and wisdom behind the CMMS' asset management strategy. PMO2000™ has been designed specifically to fill the hole left between CMMS information and reliability strategy. It is a rapid implementation system that can be used to deploy either PM Optimisation or the more formal approaches to RCM analysis.

PMO2000™ is a tool that stores the maintenance strategy / program for a company's assets and electronically outputs these into documents (normally MS Word) easily accessible to most CMMS. Electronic linking with CMMS can be examined on a case-by-case basis.

A major feature of the software is the ease with which changes to strategy can be made and documented as plant or operating conditions change. Using PMO2000™, the maintenance strategy can be instantly changed and output into schedules with the stroke of a few keys.

PMO2000™ has empirical thought processes and is ideal for organisations where failure history data is sketchy. Use of the software can be tailored to suit the level of analysis required and the significance of available data.

KEY FEATURES

Key features of PMO2000™ are as follows:

- User interfaces are designed for use by shop floor personnel who may have limited computer literacy.
- Task analysis can be completed in only one screen.
- Full implementation can be completed in three screens as follows:
  - Analysis,
  - Approval, and
  - Implementation Verification.

  Each screen can be password protected using an inbuilt security protocol.
- The software steps ensure consideration and consistency of the conditions to be inspected, the limits of acceptability and the action to be taken if the limits are exceeded.
- Both PM Optimisation and RCM methods are fully supported. Zero based Failure Mode Effect and Criticality Analysis (FMECA) is a feature included for use in the design of new equipment whether the design is a totally new concept or an upgrade of a previous model. The software is therefore a living tool from the equipment

concept design to decommissioning.

- Maintenance analysis can be completed rapidly using single screen analysis or, where required, rigorous analysis using cost benefit calculations. All analysis can be fully costed and the returns calculated by in-built intelligent cost calculators.
- Cloning or duplication of maintenance analysis is fully supported by drag and drop facility similar to the copy and paste function in Windows Explorer. This removes a significant administrative burden where there are many items of identical plant or where there is a need to apply unilateral maintenance policy to groups of common components with like failure modes and similar failure consequences. This also makes available features such as equipment and strategy libraries.
- Single tasks can be assigned to multiple hierarchical schedules such as monthly, three monthly, six monthly and annually. The order that the task appears on each schedule can be set for each schedule independently. There is therefore no need to retype each task on each hierarchical servicing.
- The labour content for each schedule can be calculated by adding the content for each individual task or by assigning a global labour content for the schedule as a work package.
- All changes to the maintenance program are archived on final approval for implementation. At any subsequent time, the rationale for changes to each task can be easily viewed no matter how many changes are made to the same task.
- Work arising from the analysis (such as writing operating procedures or assessing modifications) is allocated to people during the analysis via the software. Management of this work can be controlled via the software.
- Following implementation approval the relevant maintenance schedules are electronically and automatically updated. Maintenance schedules can be linked to CMMS via Hyperlink functions.
- Whilst there are several inbuilt reports, the report writing functionality is limited only by imagination as the database can be queried and reported on using MS Access, Excel or other like tools.
- The system can be used and operated by many people at once using a centralised database.

SPECIFICATION

The operating system requires a minimum of Win95 and will therefore run on all successors Win98, NT, Win2000 and Win XP and XP Pro.

Minimum screen resolutions are 800 by 600 pixels.

Minimum hardware configuration is 800 MHz Pentium 3 with 256 Mb of RAM and 200 Mb of free disc space growing to 100 Mb for large sites.

Software is developed in Delphi 2006 using either a SQL Server or a Microsoft Access database. SQL Server or MS Access licenses will not be required since PMO2000™ comes bundled with driver DLL's.

Reporting and schedule merge capability can be through MS Word, RTF. Adobe Acrobat or Crystal Reports.

CREATING INTERFACES BETWEEN PMO2000™ AND CMMS

There are three approaches to using PMO2000™ task information. These are described below:

USING PMO2000™ SCHEDULES MODULE AND CMMS HYPERLINK

PMO2000™ has been designed to create PM work orders in Microsoft Word. These can also be made into PDF files if the user has access to Adobe Acrobat reader. For this reason, a direct electronic interface between PMO2000™ and any modern CMMS is not a necessity.

This method entails planning and scheduling the work through the normal functionality of the CMMS. The work package output as a document from PMO2000™ is then linked as an attachment to the CMMS work order. Any comments and records are fed back into the CMMS against the work order, along with the man-hours, materials and other normal inputs.

This is the most common use of PMO2000™. The reasons organisations prefer this arrangement are as follows:

- this is the most simple and error free method,
- changes to tasks on the PM Schedules in PMO2000™ do not have to be further changed in the CMMS, and
- the schedule layout and content can be user defined so end user needs are specifically addressed.

CREATE A SECONDARY INTERFACE MODULE.

PMO2000™ can output schedules in MS Excel format. This option is as follows:

1. Export the PM schedule from PMO2000™ into Excel,
2. Export Corrective work from the CMMS into Excel.
3. Merge the scope of work into the one system (Excel, MS Access, MS Project or similar) and issue the single work plant for the outage in a format that suits local needs.

The advantage of this approach is that the corrective maintenance can be scheduled within the PM routine which reduces the documentation required and makes the execution of the work very simple**.**

CREATE AN ELECTRONIC INTERFACE.

PMO2000™ can be seamlessly interfaced with established CMMS. This has been achieved with some CMMS systems.

REFERENCES

Current users of our PMO2000™ methodologies number in their hundreds. The following list is a selection of users:

Chemicals, Oil and Gas

- Aera Energy (USA) (Winners of the North American Maintenance Excellence two times running)
- Shell Philippines
- Singapore Refinery (Singapore)
- OilSearch (Papua New Guinea)
- Santos (Cooper Basin)
- Chevron Caltex Terminals (Singapore)
- Pertamina (Indonesia)
- Australian Vinyls
- Millennium Chemicals
- Saudi Aramco Shell Refinery (Saudi Arabia)
- Qenos
- Millennium Chemicals
- Transocean Deep Water Drilling

Mining and Minerals Processing

- Billiton Mitsubishi Alliance – (Corporate rollout across seven sites using one central database).
- BHP Billiton – 25 sites including above,
- Alcoa Australia
- BlueScope Steel (two sites to date)
- One Steel (two sites to date)
- Rio Tinto – over a dozen sites
- Austral Coal
- Worsley Alumina
- Xstrata Copper (ex MIM)
- Hillside Aluminium (South Africa)
- Anglesey Aluminium (Wales)
- TiWest
- Blue Circle Southern Cement
- Richards Bay Minerals (South Africa)
- Fortescue

Manufacturing, Food and Beverage, Pharmaceuticals

- Ford Australia,
- CSR Building Products
- Fonterra,
- Kraft Asia Pacific,
- Foster's Australia (Former Carlton United Beverages)
- Goodman Fielder
- Cerestar (Holland)
- Amcor Fibre Packaging
- Phillip Morris
- Note Printing Australia
- General Cable
- Alphapharm

Power

- Bermuda Electric Light Company
- Siemens Power station Philippines
- Alinta
- GRES Power (Russia)

Other

- Kuala Lumpur International Airport
- Hampton Affiliates (Lumber mill)
- Port Warratah Coal (Port)
- Patrick Stevedores (Port)

Johnson L.P (1995) "Improving Equipment Reliability and Plant Efficiency through PM Optimisation at Kewaunee Nuclear Power Plant" SMRP 3rd Annual Conference, Chicago Illinois.

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PMOptimisation web site at www.pmoptimisation.com