

# Reliability Centered Maintenance

An Introduction for the New Reliability Engineer

by Umeet Bhachu, E.I.T.

**W**hat is RCM? By definition "Reliability is the ability of a person or system to perform and maintain its function under routine circumstances, as well as hostile or un-expected circumstances". When we apply this to accommodate and optimize the maintenance requirements of physical assets such as pumps, compressors, turbines and various other pieces of machinery typically found in an industrial set-up in a continuous improvement framework, that is what constitutes the process of Reliability Centered Maintenance (RCM).

The correct approach is in understanding RCM as a process rather than a set of specific rules that guide us in determining the predictive, preventative and corrective actions that must be taken in order to ensure that a physical asset performs to its required expectations. The basis of such actions and strategies takes into account the economics, environmental, safety and operational criteria for the asset in the given operating circumstances. The set of maintenance decisions made to ensure that such conditions are met within justifiable cost budgets, and causing minimal impact to operations, are developed by carefully applying the RCM process. One of the key motivations of applying RCM is its ability to optimize operational expenditures by rationalizing the maintenance decision making process. This is achieved by shifting the maintenance approach from a reactive model to a proactive model, performing on-going maintenance and monitoring of assets during their operation (proactive) as opposed to performing maintenance only at failure (reactive). It is important to realize that keeping the RCM process live during the service life of equipment helps to increase its effectiveness because it maintains a constant review of the maintenance routines performed on a particular asset and allows the maintenance decision making process to change as new experience is gained during its operational life. Think of this as a feedback loop to correct and improvise on past errors.

In my opinion, a person applying the RCM process needs to ask the question, "Is RCM truly needed in this particular situation?" It is very important to first assess if implementing an RCM would be the cost effective way to fine tune the maintenance requirements or if exploring other options, such as replacing failed parts or perhaps up-grading to a better design, might better serve the purpose. There are many factors that contribute to equipment failure and its frequency, and an RCM effort requires a lot of due-diligence, experience, effort and motivation on the part of maintenance and operation personnel involved in making it a success. Implementing RCM in a larger organization such as a refinery is a very involved and laborious task and would do more harm than good if not properly planned and implemented.

## Fundamental Principles of RCM

The RCM process emphasizes the use of both predictive and the more traditional preventative maintenance strategies. From an operational point of view RCM must take into account the consequences of equipment functions and functional failures. Every failure mode needs to be considered in a logical manner to determine if maintenance is required and what action needs to be taken. Predictive maintenance is performed while the equipment is in operation to determine the future trend of the equipment and the probability of failure in the future. Predictive maintenance is a cost effective approach since, in most cases, it does not disrupt the normal functioning of the equipment. The goal of predictive maintenance is to either continuously or intermittently monitor equipment so that you can identify defects before functional failure occurs. Maintenance can then be planned and scheduled to occur at a cost efficient time based on the data gathered by the monitoring process and the operation schedule. Hence, it is often also referred to as condition monitoring.

In contrast, preventative maintenance is a complete overhauling of equipment, whether or not it is warranted at a given point in time. As an analogy, it can be thought of as the routine maintenance performed on cars after a regular interval of time, irrespective of the condition. While this approach was useful in many industrial settings in the not so distant past, the complexity, size and scope of modern machinery makes carrying out such a strategy, in many cases, costly and inefficient.

Prior to and while implementing the RCM, it is important to answer a series of questions that were initially developed by John Moubray, and which still form a crucial groundwork for developing the RCM plan.

1. What are the functions and associated performance standards of the asset in its present operating context?
2. In what ways does it fail to fulfill its functions?
3. What causes each functional failure?

4. What happens when each failure occurs?
5. In what way does each failure matter?
6. What can be done to predict or prevent each failure?
7. What should be done if a suitable proactive task cannot be found?

These questions should provide a good guideline and framework to follow during setting up and directing the process. However, along with answering these questions, the RCM analyst should bear in mind that the purpose of implementing the RCM in the first place is to reduce maintenance cost and increase asset efficiency. Merely addressing the above questions in a narrow context will lead to an unsuccessful RCM program and higher maintenance costs, which would do the organization more harm than good. For instance, both long term and short term failure consequences should be examined. Careful note should be made of the cross discipline issues involved with the various functional failures, i.e. instrumentation, electrical failure modes, etc. We could have a failing in-board mechanical seal because the pressure gauge mounted on the in-board seal malfunctioned, leading to an incorrect assessment of the condition of the seal, leading to its eventual failure. It would also be wise to take into consideration the size of implementation, and if enough experienced staff could be made available without tying up the other functions of the organization.

In the past, a number of world class organizations have come to the realization that RCM is costing them a lot of money and was increasing year after year. Having introduced all the requirements of RCM, the conclusion was that while a company was profitable, the maintenance department was not and it fell below the expected standards.

### **The Decision to Apply and Implement the RCM Process – A Practical Look**

Arriving at the decision to implement and carry through with the RCM process is the most difficult stage of the process. Making this decision requires efficient planning and resourcefulness on the part of management and the rest of the teams. I will walk through a practical example that highlights the various questions that are encountered during implementation.

In contrast to failures encountered in some of the other industries, the failures encountered in process plants are random. An aircraft hydraulic pump operates under predictable circumstances, where as a crude pump in a

refinery application has many constraints and probabilities of failures, such as operator error, alignment issues, lube oil contamination, etc. One might argue the fact that it would be more appropriate to fully investigate such issues at the pre-design stage, which would prove to be much more economical than spending the money, and tying up entire teams of people, to perform a Failure Modes and Effects Analysis (FMEA).

From a practical standpoint, I have noticed a lot of pumps in many refineries failing as a result of bearing failures. These bearing failures, among other things, are a result of lube oil contamination by water and various other particulates. If one were to replace all the bearings on the 600 plus pumps in a refinery, that would translate into a great deal of money. Applying an RCM/FMEA process on such an application would, again, be very costly, time consuming and might not justify the cost of implementing the modification changes identified by FMEA. On the other hand, tackling this issue at the pre-design stage by taking into account the cause of such failures and designing better bearing protectors would be an efficient and economical approach.

A great deal of complexity comes into play when trying to decide and implement RCM on failures that are random in nature and have multiple constraints as seen above. Usually a good approach in such circumstances is to emphasize predictive or condition based maintenance in order to prevent and reliably recognize such failure prior to their occurrences.

The challenges involved in implementing RCM can lead to certain important questions that one should ask during the planning stage to explore other, possibly more efficient avenues than RCM. These would include:

1. What is the weakest component in an equipment failure and can we equate it to the equipment lifecycle?
2. Is it better to implement RCM in-house or hire an external consultant?
3. What is the cost outcome of implementing various decisions with and without RCM?

Answers to the above questions would help us make the process more productive and profitable.

### **Tools Used in Implementing RCM**

There are various tools that are used in per-

forming the RCM analysis and establishing a cause-effect relationship between system failures and performance. Some of the analytical tools used are:

- Failure modes, Effects and Criticality Analysis (FMECA)
- Root Cause Analysis (RCA) & Fault Tree Analysis (FTA)
- Risk Based Analysis (Using a control matrix)
- Weibull Analysis (Statistical modeling of failures)

Every tool plays an important part in the analysis process, and in determining the possible causes and effects of failures. Failure modes, Effects and Criticality Analysis is a frequently used tool that helps to prioritize causes of failures based on their potential consequences and probabilities of occurrence, and to classify actions that could be taken to mitigate their harmful effects on the process. A simple FMECA analysis can be performed on paper or using Excel. There are also many software packages on the market today that are used for more complex analysis performed at larger sites such as manufacturing plants and petroleum refineries.

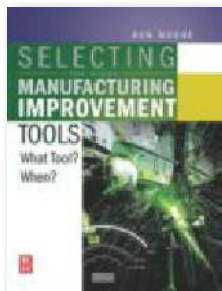
On the statistical end, Weibull Analysis is an excellent tool that can be used to study and relate the effects of performing maintenance on particular assets and their failure rates. Excel can be used in performing this simple, yet very useful, analysis to study if certain maintenance decisions implemented as a result of the RCM process were successful in reaching their target. Like FMECA and other tools, various software packages can also be used to perform advanced Weibull Analysis which takes into account complex parameters. It is well known that the 'Bathtub Curve' in reliability engineering helps to categorize the various failure rates versus time. A product batch that follows the classic bathtub curve will have a higher failure rate at the beginning of the product's life (labeled as Infant Mortality, which might be due to poor design of the product). The curve decreases over time into a relatively constant failure rate, with the failures occurring as a result of random circumstances, which are hard to prevent. However, these failures can be mitigated through accurate condition monitoring and predictive techniques. The final phase of the curve takes an up-ward slope of increasing failures, which happen as a result of age and normal wear and tear of the product. Weibull analysis helps us in understanding these failures by plotting



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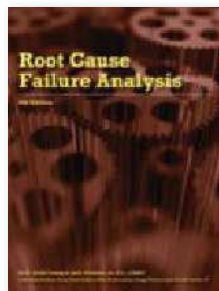
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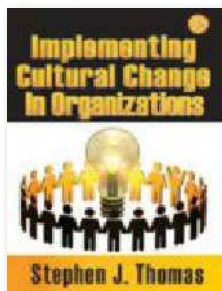
### Selecting the Right Manufacturing Improvement Tools by Ron Moore, Author of Selecting the Right Manufacturing Improvement Tools

This 9 part workshop series provides an excellent review of the most popular improvement tools and strategies - Lean Manufacturing, Kaizen, including 5S, Kanban, Quick Changeover, and Standardization, Total Productive Maintenance, Six Sigma, Supply Chain Management, Reliability Centered Maintenance, Predictive Maintenance (or Condition Monitoring), and Root Cause Analysis.



### Root Cause Failure Analysis by Jack Nicholas Jr., Coauthor and editor of Root Cause Failure Analysis

This 12 part workshop series provides an outline presentation of fundamentals of root cause failure analysis (RCFA) theory and practice. Special guest presenters include Neville Sachs, Mark Galley, Robert Latino and more. Two motor failure case studies are also included.



### Creating Cultural Change for Maintenance & Reliability Professionals by Steve Thomas, Author of Implementing Cultural Change In Organizations

This 3 part web workshop series demystifies the concept of organizational culture and links it with the eight elements of change: leadership, work process, structure, group learning, technology, communication, interrelationships, and rewards. If you want to break the cycle of failed improvement programs and instead use cultural change to help make significant and lasting improvements in plant performance, this book will show you how.



### Reliability-Centered Lubrication by Mike Johnson, Independent Machinery Lubrication Expert

This 12 part workshop series based on a Society for Tribologists and Lubrication Engineers (STLE) series of papers provides a technically precise machine re-lubrication plan which is one of the more important functions that plant management can provide to protect plant productivity.



### Electrical Reliability & Arc Flash Web Workshops led by Independent Experts

Please join us for a 10 part Reliability Roadmap Web Workshop series designed to enhance electrical safety. There is a fair amount of confusion and misunderstanding in terms of Arc Flash, NFPA 70E, CSA Z462 and other issues surrounding electrical safety. This series brings together a series of leading experts to provide a clear understanding of today's standards and what constitutes best practice.



### Infrared Thermography Level 1 by Wayne Ruddock, Independent Infrared Expert

This 23 part course follows the recommended training requirements of ASNT for Level 1 Thermal/Infrared Certification. The hands-on workshops ensure that the participants should have mastered the skills necessary to not only operate their infrared system but to perform various inspections and report on their findings.

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them against 'Median Rank' which is an estimate of the proportion of the population that will fail by a certain number of operational cycles. The plot gives us the Weibull shape parameter called Beta ( $\beta$ ) among other things. When  $\beta$  is less than 1, we know that the failure rate of the population is decreasing, which could suggest that the maintenance or design changes implemented as a result of RCM have been successful. When  $\beta$  is equal to 1, the population will have a constant or random failure rate, in which case one should stress condition monitoring methodologies. Finally if  $\beta$  is greater than 1, the population has an increasing failure rate and options such as run to failure or design changes need to be exploited. As a note, it's worth mentioning that Weibull Analysis constitutes an important tool in determining warranty requirements. Since it is capable of determining, at the very least, the probability of failure associated with an asset or design after a given number of cycles or time frame, it is capable of generating important analytical data in determining how much warranty a particular asset should be given based on its design to failure, thereby improving odds against competition.

There are other tools such as Risk Based Inspection (RBI) to determine and develop reliability and maintenance routines. The RBI process takes into account economic impact, danger to environment and safety, probability of occurrences and classifies actions based on a Risk Matrix to develop a maintenance program to tackle higher risks task first, followed by the ones lower in priority. This helps reduce costs and equipment downtime during plant shutdowns. It is a particularly useful tool used in the pulp and paper industry as part of the asset management program.

### Concluding RCM and its Advantages

Implementing RCM can provide potential benefits to specific organizations if it is selectively chosen and planned. It is a process that should be slowly and progressively implemented in larger organizations to avoid confusion or making it a too cumbersome for maintenance management.

First and foremost, it helps to increase asset efficiency, which translates into better productivity and cost savings for organizations seeking to cut maintenance vis-à-vis operating costs. Some of the other benefits derived can include:

- Better public and environmental safety
- Better view of resource requirements

that help implement efficient Enterprise Resource Planning (ERP) strategies.

- Motivation to perform in a team environment and better team building
- Development of a concise and comprehensive database of information

Reliability Centered Maintenance is not a quick fix solution for maintenance problems, and it requires planning and management support for successful implementation. The approach requires a team effort at the management and technical level to accomplish its directives. It is an active approach in that it requires active participation and live implementation by operating, maintenance and design personnel. Since its introduction in the aircraft industry during the early 80's, RCM has helped a multitude of companies across the spectrum of industries to increase uptime and become more competitive in the marketplace. It would advantageous for engineers new to this field to explore, plan and, if found viable, to implement best practices within the RCM framework to help their organizations reduce costs, prioritize safety and dramatically cut down-time and equipment failure rates.

### References

1. Moubray, John. Reliability-Centered Maintenance. Industrial Press. New York, NY. 1997

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