

A Common Misunderstanding about Reliability Centred Maintenance *Using the RCM methodology does not instil RCM discipline.*

Abstract

A Common Misunderstanding about Reliability Centered Maintenance: Reliability Centred Maintenance (RCM) was developed by the aircraft industry and it has now migrated into industries across the world. The aircraft industry does RCM differently to other industries. RCM fails in general industry because inherent problems in the business design of most organisations are prevented in the airline industry with business processes imposed by legal regulation. Using the RCM methodology does not instil the business disciplines needed for RCM to deliver its benefits.

Keywords: predictive maintenance, on-condition maintenance, condition-based maintenance, RCM methodology, reliability centered maintenance

RCM was first described in the 1978 Nolan and Heap report for United Airlines—Reliability Centered Maintenance¹ and subsequently popularised by the late John Moubray in his RCM II books². RCM was intended by Nolan and Heap for the development of aircraft scheduled maintenance programs based on safety and operational risk control reasons for a maintenance activity. The first paragraph from the Preface of their RCM report says:

“This volume provides the first discussion of reliability centered maintenance as a logical discipline for the development of scheduled-maintenance programs. The objective of such programs is to realise the inherent reliability capabilities of the equipment for which they are designed, and to do so at minimum cost. Each scheduled-maintenance task in an RCM program is generated for an identifiable and explicit reason. The consequences of each failure possibility are evaluated, and the failures are then classified according to the severity of their consequences. Then for all significant items – those whose failure involves operating safety or has major economic consequences – proposed tasks are evaluated according to specific criteria of applicability and effectiveness. The resulting scheduled-maintenance program thus includes all the tasks necessary to protect safety and operating reliability, and only the tasks that will accomplish this objective.”

The RCM methodology guides us to make maintenance strategy choices using the four equipment operating decisions known to Nolan and Heap in 1978—to run-to-failure when consequences permit, to do preventive maintenance and replace aged parts, to do predictive maintenance and look for parts’ failure initiation, or to redesign the equipment to remove failure causes (today we have an additional, better strategy—Precision Maintenance). RCM replaces time based maintenance with on-condition maintenance wherever possible.

RCM should produce the perfect maintenance program—the least maintenance costs for low operational risk and high equipment reliability. These are the reasons companies across the world initiate RCM studies for their businesses. But there are plentiful examples and forum-chat on the Internet that the hoped-for results seldom follow. There are inherent business design reasons why RCM works in the airline and nuclear industries³ but does not work in general industry.

¹ Nowlan, F.S. Heap, H.F., *Reliability Centered Maintenance*, Report A066-579, 1978

² Moubray, John., *RCMII Reliability Centered Maintenance*, Second Edition, Industrial Press, 1997

³ Bloom, Neil B., *Reliability Centered Maintenance implementation made simple*, McGraw-Hill, 2006

To understand why RCM so often fails to work in general industry it is necessary to explore what happens in general industries that is not present in the airline industry. Figure 1 shows the concept of the P-F curve, or degradation curve, made popular by Moubray's books to explain predictive maintenance and when to do condition monitoring.

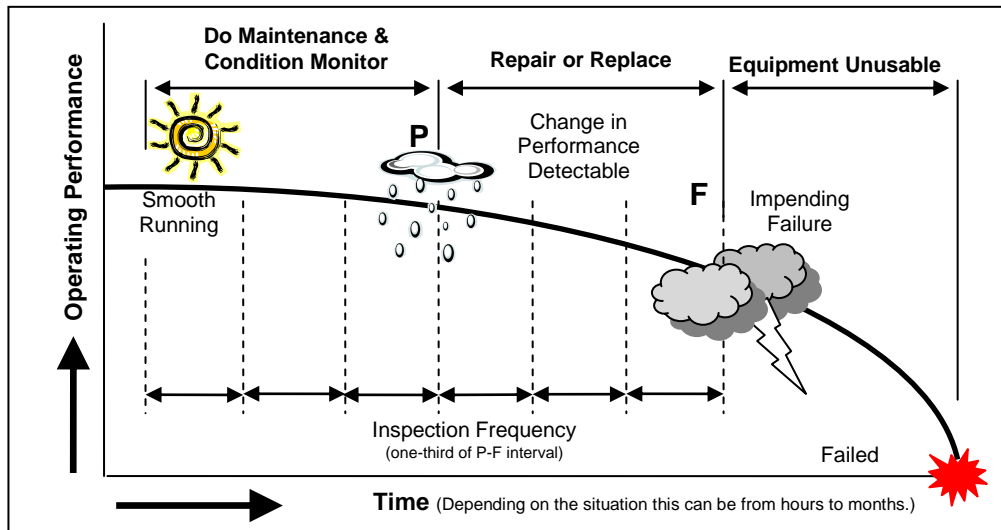


Figure 1 – The P-F Curve showing the P-F Interval

The P-F interval is the time between when a budding failure identifies itself to us (the Potential failure point 'P') and when we can no longer use the equipment because its performance degrades to an unacceptable level (the Functional failure point 'F'). An example would be a pump designed for a specific duty in which the impeller wears until the pump cannot deliver the necessary minimum flow. When a lower flow is first noted it is the 'P' point and when the impeller cannot deliver adequate flow it is the 'F' point. The pump still operates and it has not broken down, but it is not meeting its minimum functional duty.

The concept of the P-F curve applies to every part in a machine. For a machine with ten working parts every part has its own P-F curve. Condition monitoring is used to observe the 'P' point and identify an impending failure. Normally only the vital parts that lead to a breakdown are placed under observation. The 'P-F' interval is typically selected based on the worst case failure suffered on-site with the equipment item, or by using the failure history from other comparable operations, or by making a reliability failure assessment of the item.

The P-F interval is probabilistic and varies depending on the level of stresses carried by components and the number of over-stress incidents suffered by a part. Where there are many causes of high stress there are many chances to fail. With a properly set-up pump on water service operated properly the stress effects causing wear on the impeller accumulate slowly and the P-F interval for the impeller will be decades, whereas for a pump impeller on slurry service continually in contact with abrasive material the P-F interval maybe months. The water pump impeller might be condition monitored every five years, but the slurry pump impeller would be monitored every fortnight.

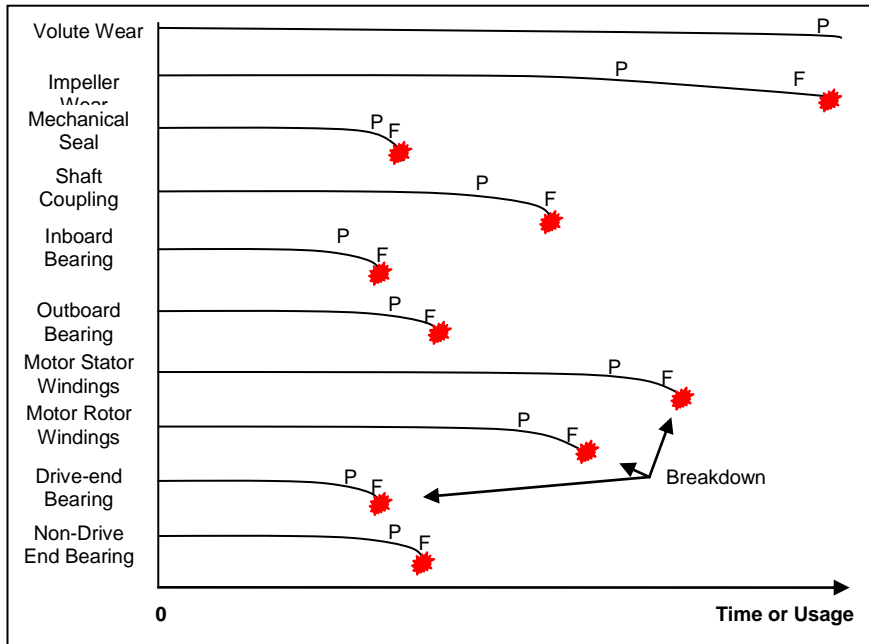


Figure 2 – The P-F Curves with P-F Intervals for Ten Pump Parts or Assemblies

In Figure 2 are represented P-F curves for ten of the critical working parts or assemblies in a centrifugal pump set working in a nonaggressive duty. Some parts can fail quickly once failure is initiated, like a mechanical seal or a roller bearing, and the P-F interval can be only a matter of days. For other parts the P-F window is measured in weeks and even months after failure starts.

Because the P-F interval is situational dependent it makes matters difficult for us when we find the ‘P’ point. From when an impending failure is identified with condition monitoring to the time an item is functionally failed there can be little time left before the part fails and the machine breaks down. Knowing that a failure has started we have to decide how quickly to act to prevent a breakdown. Because we do not know the previous operating life stresses suffered by the equipment part we naturally assume the worst and decide accordingly. The condition monitoring meant to prevent failure now acts to create reactive maintenance. If the ‘P’ point is missed or misunderstood for any reason then the breakdown happens anyway and reactive maintenance is again produced.

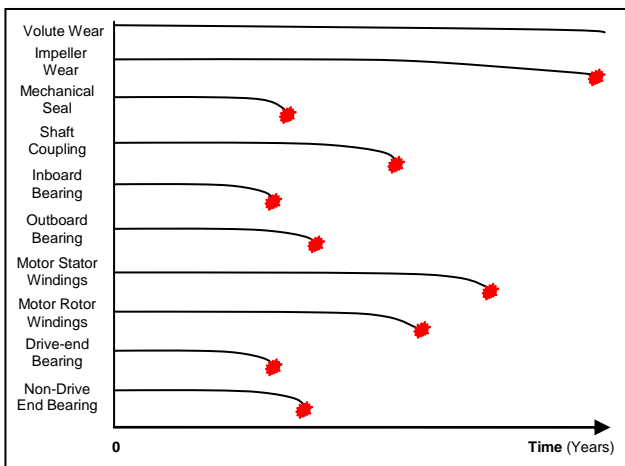


Figure 3 – Breakdown Maintenance

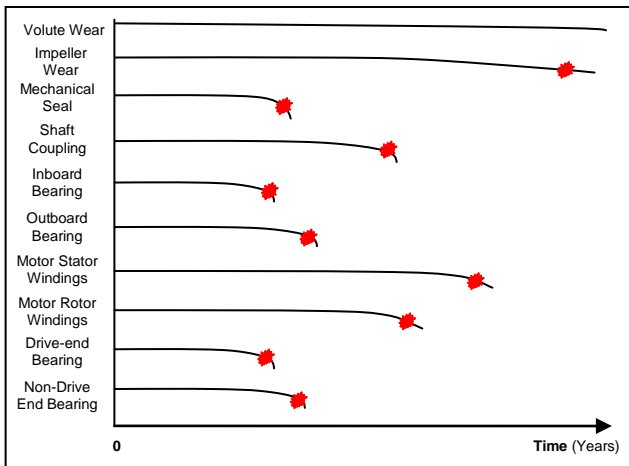


Figure 4 – Predictive Maintenance

Figures 3 and 4 compare reactive breakdown strategy with predictive maintenance strategy for our ten centrifugal pump parts. Breakdown maintenance lets equipment fail. Predictive maintenance lets equipment run to their functional failure point. If equipment is permitted to run to the functional failure point the effect on maintenance behaviour is little different to the effect of using breakdown maintenance. The inherent design of Predictive Maintenance risks creating breakdown-like behaviour on an organisation.

It is the single requirement to spot the potential failure point ‘P’ that makes Predictive Maintenance substantially different to Breakdown Maintenance.

Predictive Maintenance provides the opportunity to prevent equipment failure and plan rectification before the breakdown. How much more effective Predictive Maintenance strategy is above Breakdown Strategy depends on how wide the P-F window is for the item under observation. With plenty of warning (at least several weeks) the rectification can be planned and breakdown prevented (though production is still stopped for the maintenance duration). When the P-F interval is only a few days the resulting organisational and workplace actions are much like a breakdown. In such situations predictive maintenance, and by implication Reliability Centred Maintenance, produces the same behaviour in the organisation as does breakdown maintenance. From a corporate view point RCM has failed the business.

Furthermore we need to consider the impact of human nature, corporate reward systems and of corporate culture. Note on Figure 2 that the pump impeller P-F window is wide; it is likely to be many years before it must be replaced. The winding resistance of an electric motor can also take years to fail. How long do you think the people in a company will wait before they replace the impeller and the motor once they know that degradation has started? The case study findings below on the impact of human nature when making maintenance choices is common of industrial operations.

Back in March 2006 a large refinery installed an automated real-time, continuous monitoring system on a critical pump set to protect against cataclysmic failure⁴. It was one of many machines fitted with on-board condition monitoring as part of a refinery wide project to improve reliability. In July 2006 the pump set failed catastrophically and brought production to a standstill. The installation was state of the art with permanent temperature and vibration monitoring of bearings on the motor and pump bearing housing. The monitoring kept the operators fully aware of the equipment’s mechanical condition. It was found that the pump failed because the abundant warnings were not acted on by the operators. There were so many alarms going off throughout the plant from monitored equipment that “operators had their hands full trying to evaluate and respond”.

Where the mindset in an operation due to the prevailing culture and/or reward structure is to have minimal maintenance outages and production downtime then people will naturally wait to do maintenance. They will wait for as long as possible. They will gamble their business on another few weeks of operation, then gamble it on another few days of operation, and then it becomes too late to wait. So even for parts and assemblies with long P-F intervals human nature, corporate reward systems and workplace culture will produce reactive maintenance.

In companies that adopt RCM because RCM is supposed to stop reactive maintenance and create reliability there will be much disappointment by design.

⁴ Reeves, Todd., *Anatomy of a Pump Failure...and why it could have been prevented*, Pumps and Systems Magazine, February 2007

Yet RCM works. The evidence that RCM produces improved reliability is found in the airline industry and the nuclear industry. But these industries are abnormal. They are regulated to reduce the chance of catastrophic failures. They are stipulated by law to install the equipment, the business processes and the work practices necessary to deliver phenomenal assurance of safe operation. The resulting business design, procedures and practices are not required in general industry.

How RCM is Used in the Airline Industry

When RCM is used for aircraft the methodology is applied by the aircraft manufacturer. The preventive and predictive maintenance outcomes are written into the craft's operating and maintenance procedures that every aircraft owner is required by international law to adopt and follow. The manuals are rigorously adhered-to by highly skilled, licensed and independently tested technicians. What the aircraft manufacturer sets down in the aircraft maintenance schedule the operator must do at penalty of legal action resulting in gaol and fines for noncompliance.

The RCM outcomes that require design changes are the aircraft manufacturer's responsibility to do and to then disseminate throughout the fleet. Every design change approved by the regulating bodies must be made by the aircraft operator. Improvements in aircraft equipment and in operating and maintenance practices naturally result by the design of the regulated system in-place.

In the aircraft industry there is no choice of when a scheduled-maintenance task is done, nor of what will be done, nor of how well it must be done. When an aircraft engine or aircraft frame reaches the scheduled miles the plane must be brought in for maintenance. Already the decision has been made by the manufacturer of what parts to replace during the outage and what parts to inspect for condition. If an on-condition inspection finds a problem the plane cannot return to service until the issue is corrected. There are no options to run the plane a while longer.

The on-condition inspections are also used to gather data to extend a part's replacement interval. The aircraft manufacturers watch how their airplanes' parts age and accumulate stress. They have scientific rigor in failure monitoring and analysis. They set the limit on operating hours of parts with confidence because they know how much working life a part can expect. Only when sufficient evidence is collected across the fleet, and after a thorough scientific assessment confirms that the scheduled replacement time can be extended, are the manuals updated by the manufacturer with the new requirement. The aircraft industry has a level of quality discipline and uses business processes that ensure RCM works.

When RCM stipulates on-condition monitoring of an item it is done to minimise the chance of a breakdown by finding evidence of degradation starting. To spot failure starting in a machine the condition monitoring must be done. It is only by doing the condition observation on schedule that you can be sure the equipment is not currently at risk of failure. The inflexibility in the condition monitoring schedule is not the case for most other industries where each organisation makes its own choices when to stop production equipment and aversion to the risk of failure depends on the people present at the time the choice is made.

Conclusion

In operating equipment the P-F time window is not stable and certain. For parts that wear from use or age there is a high chance that we can judge their degradation rate and wait until nearer the 'F' point to do maintenance. But for parts that fail randomly during operation from operation-induced stresses we must immediately reduce the stress levels and start planning for rectification. The



longer we wait the more there is opportunity for known and unknown stress events to happen and produce the catastrophic breakdown we did not want. The benefit of Predictive Maintenance over Breakdown Maintenance is the extra time it gives us to act once the potential failure point is found. But miss the 'P' point or wait too long to rectify the problem and you end up in reactive behaviour.

RCM holds the potential to deliver the great reliability and safety that it promises. The intentions behind its development by Nolan and Heap can bring high commercial value to its users. But RCM requires complete compliance to an inflexible maintenance schedule in order to find the 'P' point of the degradation curve. Once the 'P' point is found RCM demands that stress levels in the item be reduced to sure safe values until rectification is completed. RCM also requires sure delivery of a specified level of task quality when doing maintenance work so equipment is returned to a known condition that produces a known minimum service life. None of these requirements are regarded as necessary in most industries and so RCM cannot work for them.

You make a common error in understanding if you think you can get the same reliability results as the airline and nuclear industries achieve without adopting comparable business systems and processes as they use. Simply by using the RCM methodology to select maintenance strategy does not imbed the RCM discipline and practices needed to get the benefits that RCM promises.

My best regards to you.

Mike Sondalini

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