Classical RCM Method and Means

by

Timothy Allen, CMRP — **AMS Associates/ JMS Software**

Eric Stevens — **Cincinnati Metropolitan Sewer District**

RCM methodology, given the 40 plus years that it has been successfully employed, and continues to be employed, to optimally maintain system functionality for platforms, plants and assets, is a remarkable process. When one considers how many other business improvement processes have come and gone during this time, it is only because the RCM process has consistently delivered exceptional value to those that have used it that this process continues to survive, grow and even thrive in today's competitive market place. Unfortunately not all processes purported to be RCM are in fact RCM. This fact was recognized long ago and drove the effort to produce RCM standard SAE JA1011- "Evaluation Criteria for Reliability-Centered Maintenance (RCM) Processes". This paper shall present the argument for conducting full Classical RCM analysis based on over fifteen years of RCM experience and observation at the US Navy's Submarine Directorate and in private industry consulting with renowned Classical RCM pioneer Anthony "Mac" Smith. The author's have seen firsthand the unsatisfactory results obtained through so-called "stream lined" RCM processes. JA1011 defines 7 steps that must be accomplished in analyzing a system by RCM. Omitting any step affects the quality and outcome of the analysis. For RCM to be done correctly all SEVEN steps must at least be thought of. And if you are thinking about all seven steps it makes no sense to not document them. We shall describe the necessity of the full RCM process to "get it right". Lastly we shall describe the most effective means to execute Mac Smith's Classical™ RCM process and the success of that process at Greater Cincinnati's Metropolitan Sewer District.

The Method

RCM is a thorough and deliberate process – a technical accounting system actually - that details the functions and functional failures of a system and methodically leads an analyst through a series of decisions to prescribe maintenance tasks to prevent or mitigate the occurrence of functional failure. When implemented, one can trace back just why a maintenance task exists and the intended benefit. It is something that makes sense, so much sense that it is truly difficult to improve upon. Yes, different aspects of the process can be accomplished in more detail as the situation merits, but the basic fundamentals of the process have withstood the test of time since the process originated in the US Airline industry in the 1960's. If we fully expect that all expenditures of a company be thoroughly documented by sound accounting standards for future audit, then why would we expect less for documenting the purpose of a company's assets and the strategy in preserving their need?

It is in our human nature to streamline and improve processes. Certainly anything that can be done to accelerate a process is worthy, but when you actually remove a critical step in the process, the results can be anything but. Removing a fundamental step from Classical RCM analysis is tantamount to removing a key ingredient from a recipe. You won't like the results.

There are currently numerous RCM "like" derivatives on the market. It is not the intent of this paper to criticize any one process or solution provider but it is the intent to alert potential RCM users of what can occur if the steps of Classical RCM are not appropriately followed. In fact, many solution providers who offer a streamlined RCM process also offer a full RCM process. To familiarize ourselves with these steps let us recount the seven steps listed in SAE specification JA1011. The specification states:

> **Any RCM process shall ensure that all of the seven questions are answered satisfactorily and are answered in the sequence shown as follows:**
>
> **a. What are the functions and associated desired standards of performance of the asset in its present operating context (functions)?**
>
> **b. In what ways can it fail to fulfill its functions (functional failures)?**
>
> **c. What causes each functional failure (failure modes)?**
>
> **d. What happens when each failure occurs (failure effects)?**
>
> **e. In what way does each failure matter (failure consequences)?**
>
> **f. What should be done to predict or prevent each functional failure (proactive tasks and task intervals)?**
>
> **g. What should be done if a suitable proactive task cannot be found (default actions)?**

Case Study

Consider the following example of what can go wrong when the fundamentals of RCM are circumvented:

A US commodity production company in the US recently invested heavily in reliability software, training and implementation of a reliability program. The company's reliability group had been working for about a year and a half developing lifecycle maintenance plans for key organizational assets to ensure continued success in bringing product to market at optimal rate and quantity. Specifically, the group had purchased a well known reliability software package to develop asset maintenance plans and condition indicators. The software had the ability to accomplish full Classical RCM but also offered a shortened process that allows the user to opt out of some of the decision methodology. The most glaring omission was the non identification of asset functions and functional failures. The software company trained company personnel to utilize the shortened analysis process for their reliability studies. Upon completion of the training, the group produced planned maintenance programs for their fleet of trucks, and other key equipment assets, and rolled out their devised PM plans to the maintenance department to improve the company's production performance.

The production company's reliability initiative was critical for a number of reasons. The company had experienced a decrease in the availability of their production assets over the past couple of years. As commodity prices increased, the company's production facilities worked around the clock - 24/7 – bringing product to market. Any interruption of that process could not be made up, and had significant lost opportunity costs. Of key concern was their fleet of trucks that transported product to a processing center. There was little reserve capacity in this truck fleet and generally all were necessary for optimal production performance. For this reason, the reliability team concentrated on this asset group first. Moreover, because each truck was identical, the return on investment in producing an optimal lifecycle maintenance plan for asset reliability was substantial. The availability of these trucks had decreased in the past two years and it was anticipated that the reliability initiative could erase that deficit and exceed historic availability levels.

Unfortunately, even after the implementation of the reliability initiative, the maintenance department was unable to maintain pace with the planned and corrective workload on the haul trucks and there was a significant backlog of corrective and overdue planned maintenance that the organization was trying to complete. There was limited time that production could give up the trucks for maintenance, and most of that time was spent on repairing breakdowns, at the expense of completing planned maintenance. Along with a general review of the reliability initiative, outside consultants were brought in to assist in the management of this backlog.

After a week of interviewing managers, maintenance personnel, and reviewing planned and corrective maintenance documents a significant number of discoveries were made. Foremost were flaws in the actual analysis process for improving asset reliability. There existed a disconnect between the relationship of degraded part conditions and actual asset or system functional failures. A significant finding was:

> **The Reliability Team, utilizing an RCM "Like" process, was analyzing all possible failures, and not necessarily focusing on the truly consequential failures, i.e. those failures that cause an asset functional failure.**
>
> **The RCM "Like" process was applied in a zero base approach - all likely failure modes were listed for a piece of equipment regardless of the function it failed to preserve. The development of maintenance on this premise leads to a maintenance program that is <u>failure adverse</u> rather than one focused on preserving asset function. Many more maintenance tasks result because of this.**

After a thorough review at the facilities the official finding was as follows:

> **"There is a systemic tendency of the Reliability Team personnel to focus on degraded part conditions and local effects without necessarily considering the higher level system and platform effects, how the failure becomes evident (observed by operations) and how the failure is causing an inability of the asset to meet a functional performance standard. The initial software training appears to have contributed to this. As a result, the analysis process in place results in the excessive identification of all possible failure modes and results in many PM inspections which are not worthwhile. Moreover, tasks that are prescribed to prevent actual consequential and functional failures often times are not rigorously evaluated to prove their technical feasibility or cost effectiveness. The frequency of accomplishing each task is often excessively conservative in comparison to the actual P-F interval (time interval from potential failure indication to actual functional failure). If the company had unlimited maintenance resources at its disposal this would not be of critical consequence. However, due to finite resources, limited maintenance bays, limited experienced maintenance personnel, and the substantial lost opportunity cost associated with taking a truck or any asset offline, the company can't afford applying its resources to activities that do not provide sufficient return on investment. The over prescription of PM's results in <u>partially completed PM's</u>, <u>overdue PM's</u>, or <u>missed PM's</u>. The actual truly critical PM's that prevent highly consequential and costly failures are being undermined by excessive "feel good" maintenance. PM's that are easily recognizable as "feel good" and not value added tends to diminish the importance of the PM program in the eyes of the maintenance practitioners which makes it difficult to enforce the accomplishment of the**

absolutely necessary and highly value added PM's which will prevent the equipment breakdowns presently occurring" (Allen)

The reason for this over prescription of planned maintenance was the decision to not analyze asset systems using the Classical Reliability Centered Maintenance process - or at the very least train all Reliability Team personnel in Classical RCM methodology and initially use that process to engrain the principles within. The RCM process is a proven methodology used worldwide with a successful track record of over 40 years. It is the recognized standard for engineering world class lifecycle maintenance plans for any asset. Only the Classical RCM methodology has the ability to take a top down, zero based approach to maintenance analysis, which starts at defining the necessary performance attributes an organization requires from its assets, and drills down through a decision methodology to ensure that there are technically feasible and worthwhile maintenance tasks in place to prevent interruption of those vital requirements. Only an experienced RCM practitioner, with significant training and implementation experience, can attempt to successfully utilize an abbreviated RCM process for a zero based maintenance program implementation. There are 7 critical steps in performing an RCM analysis, and if not all 7 steps are fully documented, they must at the very least be thought of during the analysis process. Eliminating any of those fundamental steps will lead to a maintenance program which is not optimal.

There are many other RCM "Like" processes that exist in the marketplace. Even the US Navy uses a "Backfit" RCM process to sometimes avoid full Classical RCM. The term backfit is used because it is an RCM type methodology that is employed in reverse of the classical process. A version of this process in private industry is referred to as PM Optimization. While these processes serve a purpose, as the situation merits, the Backfit and PM Optimization processes cannot be characterized as an "engineering of maintenance requirements". They are simply validation processes for existing requirements. The processes do not disclose potential failures that have no associated maintenance to prevent them. For this reason, most Backfit and PM Optimization process owners recognize that the processes should be used only if an asset has been, or intends to be, analyzed via Classical RCM. Backfit and PM Optimization are not intended as a substitute RCM process. Historically, some of the most drastic failures in industry have been failures that never happened before, that perhaps could have been envisioned and prevented if Classical RCM had been employed.

An analyst utilizing the Backfit process would devote little if any time to the investigation of substitute or complimentary maintenance requirements. While new maintenance requirements can be prescribed, the natural flow of this process does not encourage it. The entire nature of the process is to progress from the task, and work back to justify it - or not. The derivation of a new or complimentary task runs counter to this flow.

The evaluation of equipment for the prescription of maintenance is a comprehensive task. One needs to understand the system it operates in, how failure of the equipment affects the system, and the nature and consequences of failure. To effectively implement condition monitoring, there must be an evaluation of mechanics and material conditions. This is all done in tandem with extensive data evaluation. When one has invested this effort, it would be inappropriate to omit key steps and not determine the full complement of applicable and effective maintenance requirements for that asset.

We are sensitive to the concern that Classical RCM can be time consuming. This is why AMS Associates advocates the 80/20 rule in prioritizing where to initially apply RCM. For systems and components that are not as critical one could give consideration to an alternative evaluation process; however a critical system today may not be a critical system tomorrow. The failures that have happened in the past do not necessarily predict the failures that are going to occur in the future. In our experience the level of effort for Classical RCM is proportional to the criticality of the asset. If the asset is less critical then others, there will be less functional failures associated with it, less dominant failure modes, and less preventive maintenance decisions. If it is not critical, those assumptions and determinations will be documented and archived within the organization's Classical RCM library. Learning alternative methods and maintaining separate databases may distract or consume additional time and expense. If one is going to go to the trouble of studying a system, a system that by most accounts required a considerable capital outlay, may be in use for decades and exists for the purpose of accomplishing valuable firm business, one should think long term and give serious consideration to using the tried and true Classical RCM process to document and preserve the intent and need for that system.

Means

The means by which RCM is executed has been attempted in many ways.   Each manner has its pros and cons and the method preferred by AMS Associates is one that is most likely to be accurate, successfully implemented and sustained. That model is one that includes the stakeholders, the people that actually maintain and operate the equipment. They have much vested in the success of the initiative as they are the ones that will reap the rewards or suffer the consequences. Often times an RCM project is the one time that a person on the frontlines - fighting the fight war against friction, wear, and failure - is given an opportunity to have a voice or say in how the systems and equipment are maintained and operated.

We recognize that RCM can be accomplished by an outsider. Sometimes outsiders can be change agents where change is necessary. To that extent, there needs to be a blend of outside thought and inside knowledge and experience. It has been demonstrated over and over that when an outside consultant does the lion's share of the analysis the probability of new recommendations actually being implemented is remote. They may be very good ideas, but often times there is insufficient gravity or momentum to act on these ideas. Moreover, it is extremely difficult for an outsider to become proficient on how someone else's system operates and behaves.

The following author observation was made at the US Navy's Submarine Maintenance Engineering, Planning and Procurement (SUBMEPP) Activity in a discussion to maintain control of accomplishing RCM internally to the organization:

> **"Clearly the long term interests of SUBMEPP lie in the cultivation of our engineering expertise, to which the accomplishment of RCM analyses by engineering serves. For knowledge worker businesses the number one detriment to sustained gains in organizational productivity is the loss of corporate knowledge. Engineer accomplished RCM fights those losses with vengeance. Like the old proverb states – "Give a man a fish and you feed him for a day. Teach a man to fish and you feed him for a lifetime". Our belief in RCM, and professional satisfaction, lies in creating experienced RCM advocates throughout our organization. The dividends beyond the initial metric cannot be overlooked. When our engineers face off against their colleagues in competing engineering organizations at Maintenance Effectiveness Review meetings and other forums, they command the high ground with their intelligence not only of their systems but how the Navy should make maintenance decisions. More and more in recent years SUBMEPP has become seen as the submarine maintenance-**

> **engineering experts. We believe that RCM has played a large role in that. We know too well from experience that a system engineer can get by doing assigned work without a full comprehension of how his or her system or component works. To the extent that that occurs SUBMEPP eventually pays a price. RCM, in effect, forces the complete understanding of the system and component analyzed. The procedure deepens the expertise of the engineer." (Allen)**

In another SUBMEPP discussion on whether full time RCM practitioners should perform RCM analysis rather than the actual system engineers responsible for the assets, the author observed:

> "**A team of permanent RCM practitioners is comparable to the Permanent Analyst model, which was previously attempted and abandoned due to poor results. This past model traded one unfamiliarity for the other. Just as beginning RCM analysts struggled initially with learning and executing the RCM process, the permanent analyst struggled with learning the system and equipment. However, the investment required of the system engineer to command the RCM process is value added - it is a repeatable process and discipline they will utilize throughout their system engineering career. The struggle of the permanent analyst is a continuous struggle to command the specifics of systems and components they have no ownership of. Once the system and equipment knowledge is learned, it is generally not utilized beyond the RCM analysis at hand. A team of RCM specialists to facilitate, mentor and coach system engineers in the application or RCM is a more practical model." (Allen)**

Cincinnati Metropolitan Sewer District

Cincinnati Metropolitan Sewer District (MSD) embarked on an ambitious strategy in 2006 to significantly improve upon the reliability of their plant assets. Of chief concern was MSD's environmental impact upon the Ohio River. A vast collection system designed and constructed well over a hundred years ago, transports not only city sewerage but most all storm water runoff directly to MSD's treatment facilities. During heavy rain events it is possible, especially if critical equipment and systems are inoperable, for incoming sewerage and storm water to exceed plant capacities and not receive full treatment. For this reason, the city has numerous initiatives to minimize this occurrence as evidenced by the city's recent signing of a Global Consent Decree to improve the environmental impact of wet weather events.

Since the 2006 initiative commenced MSD has employed a number of approaches to achieve their objective of improved asset reliability. Their first approach consisted of a "Criticality Analysis" that:

1) Grouped components into functionally related equipment
2) Ranked the grouping's criticality based on qualitative criteria for safety, environment and plant operations
3) Applied "best practice" proactive maintenance plan templates based on the criticality ranking's of High, Medium and Low – with the most proactive reserved for the assets of the highest criticality

While the above process enabled MSD to roll out a maintenance program in mass in an efficient time frame, MSD considered it a "first cut". For instance, one shortcoming is that the process did not identify failure modes of the equipment, nor did it study the cause and effects of failure to apply applicable and cost worthy maintenance tasks directed specifically at those failures.

MSD’s second approach, beginning in 2009, was to employ Classical RCM analysis on key treatment systems. There were significant differences in the outcomes of these two approaches at MSD which we shall explore.

In their 2009 technical paper delivered at the WEFTEC Energy Optimization and Management conference, MSD managers John Shinn and Don Linn presented a comprehensive comparison of the two approaches mentioned above for evaluating assets. They stated “A high level of equipment availability is necessary to ensure that the treatment plant serves its function to meet wastewater discharge permit requirements”. While Shinn and Linn acknowledged that RCM is time intensive in comparison to some other maintenance evaluation methodologies they concluded that Classical RCM was more advantageous:

> **“RCM uses MSD’s expert experience to identify failure modes and develop applicable and effective maintenance tasks. The team of experts selected from the MSD’s maintenance crafts and operators typically brings over 100 years of hands – on experience with the equipment and processes. Not only does the team have the right resources available to discuss the proper operation and maintenance for each piece of equipment, each member learns a surprising amount of new information including creative approaches to identifying impending failure modes. “**
>
> **“Because RCM directly involves the staff that is tasked with managing assets, they take great ownership in the improved maintenance program. They understand it because they created it and they have a vested interest in continuing to improve it and to make sure that the maintenance plan that results from the analysis is implemented. All of this supports and reinforces the culture change to a more proactive operating environment.”**

To oversee their RCM initiative MSD obtained the services of AMS Associates along with Brown and Caldwell , a water industry consulting group, to conduct a pilot Classical RCM project on a select treatment system at Mill Creek , their largest treatment facility. After a thorough analysis of system failures and corrective maintenance costs, the plant’s Dewatering System was selected as the most well suited for a return on investment. AMS Associates advocates the 80/20 rule which states that 80 percent of plant problems are generally caused by 20 percent of the actors; therefore it is wise to focus on the 20 percent bad actors first. The Mill Creek Treatment Plant utilized its existing reliability software “BICycle™” to analyze the behavior of plant treatment systems. The parameters considered were failure rates, failure costs, and downtime hours associated with failure. The data revealed that the solids end of the plant had the most failures with Incineration and Dewatering being the 80/20 systems. Since Incineration was in the midst of reconstruction to a new design, Dewatering was the targeted system. Within the Dewatering process area, pumps, centrifuges, conveyors and instruments were the 80/20 bad actors. To perform the RCM analysis, facilitated by AMS Associates, a team was assembled comprised of maintenance and operational personnel, including a mechanic, electrician, instrument technician and system operator.

A key difference between the Classical RCM process and the “Criticality Analysis” process MSD initially utilized is RCM’s complete system perspective – the cause and effect relationship between a failure mode and the inability of a system to meet a desired parameter. An asset’s failure can have little or no effect on an organization’s mission, above and beyond the cost of repairing that asset. However if failure of an asset disturbs a “system” that is relied upon for the accomplishment of an organizational commitment, then that organization may suffer an economic loss that cannot be recovered. With MSD there is a community cost not easily measured in dollars and cents. Recall that the most critical time for

MSD is during a rain event, when their assets are most severely taxed. It is precisely “that” scenario that is envisioned during the RCM analysis process. What is the performance requirement of the system? How can it not meet that obligation? And what failure can cause the system to not meet that obligation? RCM creates a “hand crafted” maintenance program tailored specifically for the need at hand. This approach cannot help but create better strategies to maintain system availabilities and reliability.

It is important that the failure modes identified in an RCM analysis be realistic. A review of feedback data can assist in this, but generally it is the combined experience of the RCM team that will produce an accurate list. Relying only on failure data is insufficient because past PM’s may have prevented the occurrence of some failures. Indentifying dominant failure modes that cause functional failure is just part of the process. These assumptions must be further vetted by a rigorous “failure effects” discussion at the local, system and plant levels. Often times during the workshops, misconceptions are ironed out between operations and maintenance. In fact, the interactions between maintenance and operations during the RCM workshops are the secret catalyst to oftentimes very effective solutions.

Mill Creek’s Dewatering System

The Dewatering process is part of the solids end of the treatment plant. Wastewater treatment plants have two major process streams - a liquid and a solid. Through a sophisticated process of straining, settling and separation, the incoming influent is divided into two process streams, one becoming progressively more liquid and cleaner with the assistance of chemical and biological treatment for eventual discharge back into the environment, and the other becoming progressively more solid for eventual incineration.

The Dewatering system receives solid slurry from the Secondary Settling system. As it is received the solids undergo a grinding process to reduce the size of the solids, and the remaining liquid is removed in centrifuges to produce a cake (26% solid). From the centrifuges the cake transfers to a collection system which moves the cake by a system of conveyors, augers and piston pumps to an incineration plant in another building. It is extremely important that incineration be fed cake at a specific rate and cake quality or significant damage can occur to the incinerator. It is also important that the system take all the sludge it receives so not to allow excess sludge build up in the plant.

The Team used the Classical™ RCM process derived by Anthony Mac Smith of AMS Associates and executed it with RCM WorkSaver™ by JMS Software. The team was facilitated over the course of three weeks which included two days of classroom training. Portions of a fourth week were used to compile the results and present a management out brief.

Figure 1 displays the functional block diagram of the Dewatering system. Because of the complexity of the system it was further broken down into subsystems. Two subsystems were analyzed due to constraints of time during the pilot project –Centrifuges, and Collection Bin and Schwing Pumps. The Sludge Pump and Grinders sub-system was analyzed in part to prepare the assembled team for follow on work.

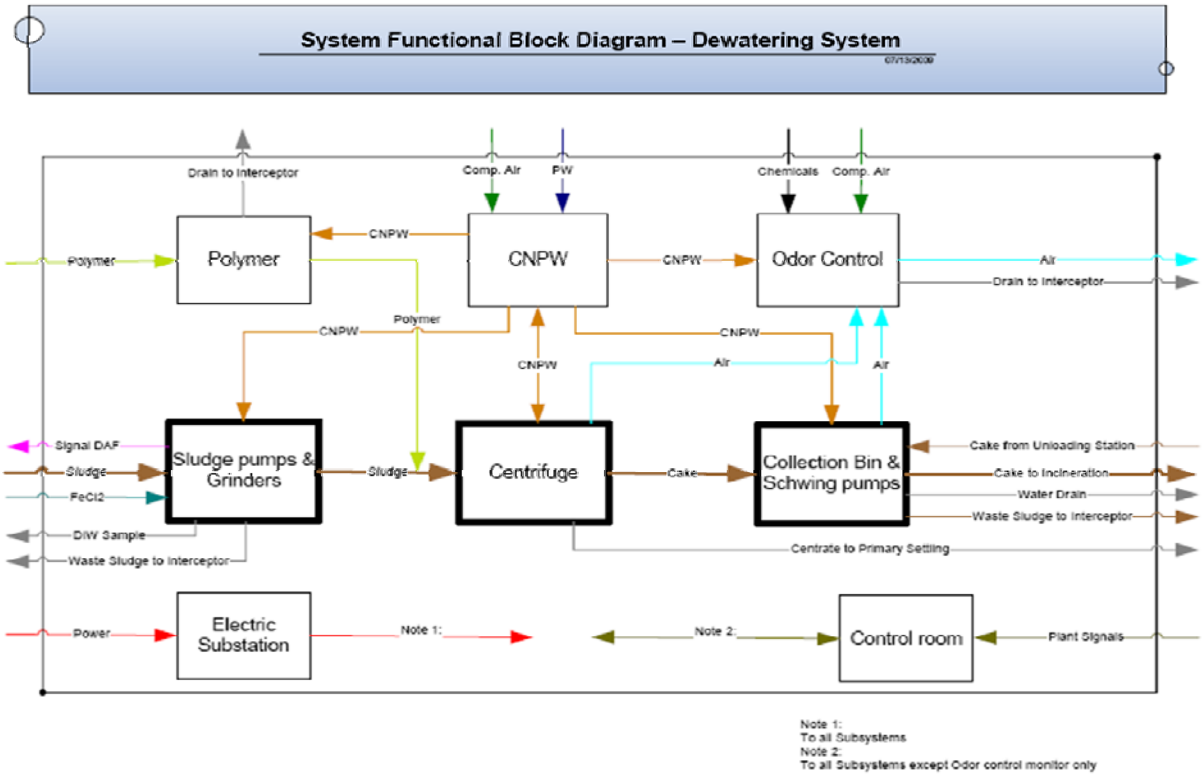

Figure 1

After thoroughly bounding and describing the system the next RCM step was to document the functions and necessary performance parameters of the system. For instance, the main function of the Centrifuge system was to:

> **Provides a means of collecting and transferring cake (26% solids) from collection bin to designated incinerator, at a flow rate as determined by plant sludge inventory (to a maximum of 12 dry tons per hour).**

From this system function the team documented four functional failures:

1. **Fails to transfer any cake**
2. **Fails to transfer sufficient cake quantity**
3. **Fails to deliver proper cake solids content %**
4. **Unable to transfer to the proper (designated) incinerator or incinerator storage bin**

Other secondary and passive functions were documented such as maintaining system fluid boundary, providing control signals and maintaining the ability to remove air/off gasses from collection bins to odor control sub-system.

In all 12 functions, 24 functional failures, 48 components and 166 failure modes were analyzed for the two dewatering sub-systems. From that the team prescribed 159 preventive maintenance tasks targeted directly at those failure modes deemed critical and capable of being prevented or forestalled. In addition to the recommended planned maintenance tasks, 37 “Items of Interest” were recorded by the team. These ideas consisted of design changes, investigations into new uses of predictive technologies and other beneficial ideas.

Number of	Collection S/S	Centrifuge S/S
System Functions	6	6
System Functional Failures	**12**	**12**
Components in System Boundary	30	18
Failure Modes Analyzed	**107**	**59**
- Critical (A,B, D/B)	102 (95%)	56 (95%)
- Hidden	**22 (21%)**	**12 (20%)**
PM Tasks Specified (including RTF)	137	81
Active PM Tasks	**101**	**58**
Items of Interest	22	15

Figure 2

Schwing Reciprocating Pump

At the heart of the Collection Bin sub-system are six identical Schwing reciprocating pumps. Each pump receives cake from an associated feed screw. The low speed positive displacement pumps push the cake through process piping to a designated fluidized bed incinerator. There are three collection bins in the sub-system. All are required at full capacity when there could be six centrifuges in operation. There are two Schwing pumps dedicated to each collection bin, and they cannot be cross connected to other collection bins. One Schwing pump can handle the output of two centrifuges; however, the two Schwing pumps that exist for each collection bin do not have the same incinerator output destination. For example, while Schwing Pump #2 may be able to output to Fluidized Bed Incinerator #2, Schwing Pump #1 only outputs to Fluidized Bed #1. Therefore the Schwing pumps are not redundant. As one can see it is precisely this detailed analysis of the capabilities of a system, usually determined and documented after substantial team discussions, that make simplistic one size fits all maintenance strategies not optimal.

Failure of a Schwing pump has the ability to reduce required cake flow to a designated incinerator making for inefficient incinerator operation. One failure mode of the Schwing pump is a “Worn Material Piston” which causes the system functional failure “Fails to Transfer Sufficient Cake Quantity”. For this reason it was classified as having an operational effect on the plant (partial outage). Moreover it was recognized that this failure would be “hidden” until there was there was sufficient demand that could not be met. While there was an intrusive PM task on the books to inspect the pump water box for contaminants – a symptom of the failure mode – there was currently no practice at the facility to monitor the actual volume output of the pumps. After a brainstorming session on how to even do this – including a teleconference call to the equipment manufacturer during the team workshop, the team devised a strategy to re-program the online PLC to enable online monitoring and trending of Schwing pump fill rates. Drop offs in cake pumping rates will now be visible to operations.

Centrifuges

Prior to commencing the RCM Pilot Project at MSD a pillow block bearing on one of the centrifuges experienced a sudden failure, putting the centrifuge out of commission until a bearing could be obtained and replaced. MSD had no warning that the bearing was in declining health. During a team visit to the Dewatering control room the operator on the team demonstrated what was visible for the centrifuge on MSD's SCADA (supervisory control and data acquisition*)* system. It was noticed that one of the bearings was exceeding proper temperature and vibration levels and in fact was drawing excess amperage. After this discovery the team members performed some troubleshooting routines to determine the cause of the bearing condition. It was soon found that the lubricating oil temperature was running high. The oil is cooled by a potable water heat exchanger. After ruling out restricted flow as a cause, the team questioned the performance of the heat exchanger. Due to the lack of temperature indicators one of the mechanics utilized a heat reading gun and obtained inlet and outlet water temperature readings. When compared to other identical heat exchangers in the system it was found that the suspect heat exchanger had insufficient heat transfer and required cleaning. We present this case because it is an excellent example of the benefits of being proactive and aware of the operating conditions of a system, and allowing system indicators to alert operations or maintenance when preventive action is necessary. Had this condition not been noticed a very expensive downtime would have occurred for MSD. It reinforces the need to specify periodic operational condition directed tasks to ward off functional failures.

Lessons Learned

Overall the initiative at MSD was quite successful. The team created numerous condition monitoring tasks such as internal camera inspections and performance tests to replace their historical time directed 16000 hour centrifuge overhaul. The team learned that if you can accurately describe the system effect of failure you are half way there to establishing and effective monitoring task. While no member of the team will agree 100% of the time with the outcome of RCM derived recommendations, the team had considerable buy in at the end.

Figure 3 compares the RCM pilot project recommendations with the MSD's existing maintenance plan which were previously derived utilizing the Criticality Analysis method. The Classical RCM process produced significantly more PM recommendations. Note that RCM specified fifteen failure finding tasks in comparison to four existing failure finding tasks. An example hidden failure was "Worn Nose Cone" on the centrifuge which would allow increased clearance on the fluid boundary surfaces and decreased cake production. In turn this would allow the production of "wet" sludge which can damage the incinerator. To counter this, the team recommended the creation of a centrifuge performance test, (efficiency, vibration, energy draw, flow rate and cake moisture content) to enable operations to know exactly when such detrimental conditions emerge.

Task Type	Collection Subsystem			
	RCM		Current	
Time Directed				
- Non-Intrusive (TD)	44	(32%)	11	(8%)
- Intrusive (TDI)	9	(7%)	13	(10%)
Condition Directed (CD)	33	(24%)	11	(8%)
Failure Finding (FF)	15	(11%)	4	(3%)
Run-to-Failure (RTF)	36	(26%)	-	
None	-		98	(72%)
Total	137	(100%)	137	(100%)
Total Active	101	(74%)	39	(28%)

Figure 3

In some instances it was determined that "Run to Failure" (RTF) was the only viable option. There are some failures that cannot be predicted or prevented and one must either accept the risk or address it by other means such as design changes.

Task Type	Collection		Centrifuge	
I. RCM Tasks = Current Tasks	22	16%	27	33%
II. RCM Tasks = Modified Current Tasks	9	(7%)	5	(6%)
III. RCM Specifies Task, No Current Task Exists	67	(49%)	26	(32%)
IV. RCM Specifies RTF, No Current Task Exists	35	(25%)	23	(27%)
V. Miscellaneous	4	(3%)	0	(0%)
Total	137	(100%)	81	(100%)

Figure 4

49% of the RCM tasks recommended by the team for the Collection sub-system and 32% of the tasks recommended for the Centrifuge sub-system had no existing counterpart in the existing maintenance plan.

This represents a significant opportunity for MSD to transition to a more proactive stance in preserving system integrity.

Overall, MSD team members learned a considerable amount about the functionality and operation of the Dewatering system and equipment. Additionally, each team member enhanced their knowledge of other crafts and disciplines. The effort produced a cultural change where team members employed new reliability strategies through the monitoring of system parameters.

A key lesson learned which was presented by the team at the management out brief was:

> **"If Operations and Maintenance pay more attention to system parameters, potential failures can be detected and action taken in time to prevent consequential failures."**

MSD team members were encouraged to provide their own comments and feedback to management on the value of the project. A team statement was crafted that stated:

> **"If the RCM recommendations are implemented we the team feel that it will benefit Mill**
>
> **Creek Treatment Plant in the long term toward improving reliability and processes. "**

Implementation

A month after the above statement was made, MSD authorized the immediate implementation of all RCM maintenance tasks and their journey to a proactive strategy of preserving critical system availability began. Since then, MSD conducted a second RCM pilot project with another team at their Little Miami Treatment Plant and is taking steps to institutionalize a "living" RCM program at other treatment plants. The Mill Creek Team continues meeting to enact their recommendations and have even adjusted the scope and frequency of some tasks based on as found conditions of the equipment. The team also convenes periodically on their own to conduct RCM for the remaining Dewatering sub-systems. MSD's computerized maintenance management system, MAXIMO, has been updated to individually account for each component that was analyzed in the studies, and to tag each as RCM analyzed. Additionally, each failure mode documented in the RCM studies is being entered into Maximo to create a corrective work order pick list to appropriately document the occurrence of any RCM component failure modes. Periodic management reports will enable MSD to measure the results of the RCM program. This continuous improvement feedback process will allow MSD to revisit their RCM studies to confirm whether past decisions are remain valid or not.

ACKNOWLEDGMENTS

The authors wish to acknowledge John Shinn of MSD who championed the RCM Pilot Program and contributed to this paper. The authors also wish to acknowledge the MSD RCM Team whose dedicated initiative made the Cincinnati Mill Creek RCM project possible; Tom Goodman, Harold Webb, Bryan Royce and Jerry Hood. Special thanks to team trainer and project director Anthony Mac Smith whose 27 years of invaluable RCM leadership are an inspiration to all.

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BIOGRAPHIES

Tim Allen is an RCM consultant and independent associate of the AMS Group. Tim is the former RCM Program Manager at Submarine Maintenance Engineering, Planning and Procurement (SUBMEPP) Activity, a Naval Sea Systems Command (NAVSEA) field activity located in Kittery, Maine. Tim worked at SUBMEPP for twenty years and was a leader in Navy RCM since 1996, where he represented the US Navy's Submarine RCM program. Since leaving the Navy, Tim has specialized in RCM consulting for 5 years under the leadership of Anthony Mac Smith, a pioneer in the field of RCM. Tim received a Bachelor of Science in Mechanical Engineering Technology at the University of Maine in 1986. In 1997, he received a Master of Business Administration degree at New Hampshire College. He can be contacted at timallen@granitereliability.com

Eric Stevens is an Instrument Technician at the Cincinnati Metropolitan Sewer District. He has worked at their Mill Creek Treatment Plant for the past four years and is a state certified Class 1 Wastewater Operator. Previously Eric was a US Navy Aviation Electronics Technician 2nd Class. Eric earned a Bachelor of Business Administration from the University of Cincinnati in 2004 and is currently pursuing an Environmental Engineering Technology degree. Eric is avid recreational airplane pilot. He may be reached at eric.stevens@cincinnati-oh.gov.