

# KEY POINTS AND SUGGESTIONS ON RCM APPLICATION IN MANUFACTURING INDUSTRY

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## Abstract

Techniques of Reliability-centered Maintenance (RCM) play an important role in maintenance and operation field of the manufacturing enterprises. It can enhance equipments reliability and reduce maintenance & operation cost. According to the RCM practices and experience in Large-scale Enterprises, this paper focuses on the key points on RCM application in manufacturing industry. It is a valuable reference for RCM applying and implementing in enterprises.

**Keywords:** Maintenance Optimization, RCM, Reliability-centered Maintenance, Suggestion

## 1 Introduction

Enterprises are facing the enormous challenges because of more and more fierce market competition. Lowering production costs and improving product quality have become the key factor that manufacturers care about. With further increase of the degree of industrialization, the costs of equipment maintenance has been rising from the perspective of the absolute volume or the proportion of the total cost. In some industry field, such as power companies, the maintenance costs have become the most important cost factor. According to the figure from U.S. statistical releases, expenses for the industrial equipments maintenance was \$250 billion, about one third of \$750 billion U.S. government tax income in 1980[3]. And the annual expenses of equipment maintenance was over \$80 billion in China, about 7~9 percentage of total asset value[4]. The industrial enterprises want to enhance their management of equipment and maintenance scientifically. They need to consider not only cost of the operation and maintenance. The safety operation and equipments reliability are also the most important factors. The enterprises try to optimize the management of equipment maintenance. It is the important topics and questions in maintenance field that what to repair, when to repair and why to repair.

Enterprises carry out preventive maintenance of equipments. What need to repair and when will repair is the first issue they should solve. As to answer the questions, the traditional approach is to discuss and carry out preventive maintenance activities according to the manufacturer recommendations or feedback data. The outline items and preventive maintenance activities are becoming more and more with the equipments aging management and administration requirements. But the

theory of RCM shows that more maintenance does not equate to higher reliability. The frequent and unnecessary preventive maintenance will not only reduce the reliability of the equipment but also increase the maintenance costs, without any benefit to improving equipment reliability. All the \$250 billion industrial equipments maintenance expenses released by U.S. government, at least \$75 billion wasted, which was used for equipments maintenance unnecessary.

RCM is a widely used engineering tool in the international industry field. It is used for determining preventive maintenance requirement of equipment assets and optimizing maintenance system. The RCM theory research originated from the 1960 U.S. aviation industry, and the maintenance program established by RCM was first applied to the Boeing 747 aircraft. In the late 1970s, RCM was introduced in the U.S. Defense industry. The standard of RCM application was formed and improved gradually on the basis of large number of theory study and application research. At present, almost all the important military equipment preventive maintenance program of the U.S. military are developed by RCM method, including the active duty and the new research equipment[6]. The domestic research and application of RCM is a little late, however, presently more and more enterprises have begun to understand the RCM and used the technology to determine a reasonable requirements for equipment maintenance.

The application of RCM techniques can bring the manufacturing enterprises substantial cost-effectiveness. Actually, the effects of RCM application are far more than that. How to develop the RCM technique successfully? What are the key elements of the RCM implementation process? The purpose of this paper is to analyze and summarize the key points and recommendations of developing RCM, by combining the author's many years experience of carrying out the maintenance optimization analysis and technology management in power station.

## 2 RCM Technique and Effects

The standard RCM process is put in practice, based on the standard criteria in *Evaluation Criteria for Reliability Centered Maintenance(RCM) Processes*[4]. According to the standard, the seven questions would be answered in the selected systems or equipments RCM analysis.

The basic approach of RCM is series activities. RCM do the function and failure analysis, evaluate failure consequence of all failure mode, determine

preventive maintenance tasks by standardized RCM logic. All the steps are useful for scientifically determining the maintenance activities requirements[7].

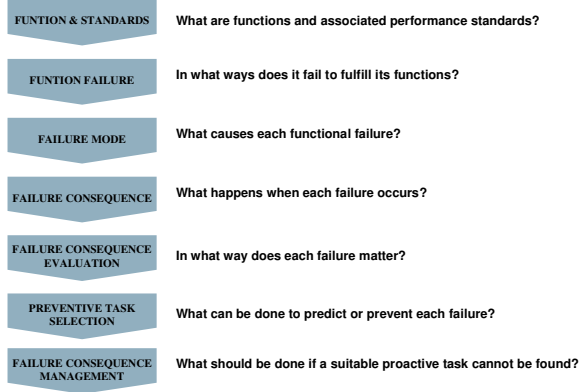


Figure 1: RCM Analysis Seven Logic Questions

It has been widely used in different industries (airlines, petroleum, petrochemicals, electricity, railways) all over the world since 1980. According the data from Plant Maintenance Resource Center, there are 60 percent of the manufacturing industries in occident countries using RCM to setup or optimize maintenance outlines. Nuclear countries such as USA, France, Korea and South Africa began working with the application of RCM years ago. It takes good effect in the countries. Daya Bay Nuclear Power Station (DNMC) of China introduced RCM in 1998. It was being carrying out after program feasibility research, personnel training and experimental system analysis. RCM brings great benefit of equipment reliability, system availability, equipment maintainability and maintenance cost reduction after more than 100 system RCM analysis experience and years RCM application in DNMC.

### 3 Key Points Analysis on RCM Application

#### 3.1 Selecting Proper RCM Organization

In general, RCM takes system as analysis object with team form carrying out. It has a typical feature of project management. For operation of a project, there are generally three options for organization structure: functional type, project type, matrix type [1]. The three forms of organization structure for project management have their own characteristics. Which organization structure will be selected for the implementation of RCM analysis may be overall considered according to the characteristic of maintenance optimization process combined with three different forms of project organization structure.

The characteristics of RCM project are taking certain analysis object and scope as the target, using normalized operational thought. The whole operation process involves in resource preparing, plan arrangement, technical analysis, cooperation and communication and other aspects. It has the features of project management organization and operation. The specific analysis process of RCM project is carried out with team form. Organization structure of functional type

does not have the advantage in assorting with many departments. Organization structure of project type has a higher efficiency due to staff comparative concentration, which is more effective to the RCM of small range. But generally enterprises are equipped with systems relates to mechanism, electric, instrument control and other specialty, the single project type organization is not the best choice for RCM organization and operation. It is more efficient using organization combined with functional type and project type.

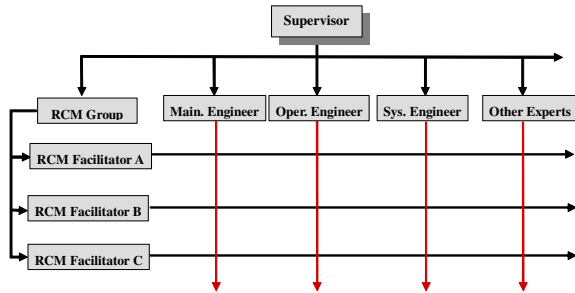


Figure 2: Matrix Organization Structure of RCM

Project is the focus of work in organization structure of matrix type. Special RCM analysis engineer, namely analysis project manager, takes responsibility of finishing the task in setting time which is beneficial to the project controlling. Because of analysis objective relates to different professional aspects and different technology, project organizational operation bases on other functional departments. Temporary engineers from professional department in the project team could resolve some technical issues they met more pertinently and improve analysis efficiency. Personnel in functional department may go back to their former department after completing analysis task and finishing the project and receive "home" feelings, which will be changed from strong connection of project organization into weak one. Due to the matrix type organization structure, there is better cooperation. The analysis results and enforceability can achieve more trust of company leadership. However, there are also shortcomings in matrix type structure. When many projects are proceeding, there are some difficulties on how to assort with manpower, resource, plan and so on. This is the time required to whole coordination and overall planning between responsible directors of maintenance optimize organization and functional department in order to achieve the optimization of organization operation.

#### 3.2 Establishing, Perfecting Application Work Flow and Interface

RCM implementation is a series of process including from analysis, to application, and to feedback, while system RCM analysis process is only the specific technical process. Because the whole work of RCM is much more systematic, enterprises need to establish a complete norm system so that the introduction and analysis work can be carried out smoothly, and the facilitators can implement the RCM analysis process and keep the continuous optimization. All these are to ensure that the analysis is of standardization and profit. The

process of RCM analysis and implementation can be divided into four stages[2].

First, Preparation Stage. This stage refers to a period of time before the start of the systematic analysis. During the stage, the facilitators need to make a plan and progress arrangement relating to a specific analysis object. They need to estimate the difficulties of the analysis process. A manpower application needs to be submitted to support the analysis. Simultaneously, in order to achieve a better analysis results, the facilitators also need to collect sufficient information correlative to the analysis objects, and confirm all the resources needed in the analysis process, such as conference rooms, supporting staff, material and tools.

Second, Analysis Stage. This stage is the specific implementation process of analysis, including define system boundary, list functions and performance standards, determine function failure, analyze failure mode, describe failure effect, evaluate failure consequence, select appropriate maintenance task and interval. All the process is also the process of answering the Seven-Questions of standard RCM process.

Third, Implementation Stage. This stage is focus on the document checking and collating, including system task summary, regulation and supervision document comparison, maintenance program comparison, assessment of the profit, review conference, document approval, task allocation, maintenance program authorization, optimizing database, task implementation, etc.

Fourth, Optimization Stage. This stage mainly refers to the feedback of the analysis mission in the implementation process. On the basis of actual operation and maintenance experience combining with internal and external lately experience feedback, the maintenance strategy need to be evaluated and further optimize, so as to enable the on-site maintenance activities more pertinence and to improve continuously the equipment reliability.

Form preparation, analysis, implementation to optimization, the maintenance optimization activities constitute a complete closed cycle. There will produce a large amount of information and need to pass between the phases as well as inside the each phase in the cycle. The information used in different phase is characterized as personal focus and intertwining each other, and eventually form a complete dynamic cycle (see fig.3). The whole RCM process reflects a train of thought of continuous improvement and optimization, which agrees with the PDCA cycle concept that advocates improving continuously effectiveness and efficiency (also known as the Deming Cycle) in the modern quality management system.

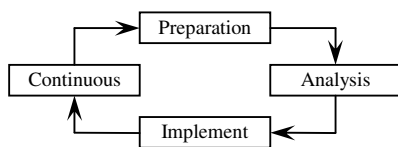


Figure 3: RCM Analysis and Implementation Process

Altogether, the whole RCM application flow need to be standardized combining different stages' work content, so that every work of RCM can be carried out step by step and high efficiently.

### 3.3 Choosing Proper RCM Decision Making Logic

From the analysis of the system function and associated performance standards, enterprises can get information of equipment function failure, failure modes, failure consequence and so on after RCM analysis and its structured question. All these information is necessary for making reasonable maintenance requirements of assets. However, how the maintenance strategy does right from the equipment failure information, it is the key three answers for the seven RCM questions. All the maintenance strategies are made by RCM decision making logic[5].

According to years RCM application and practice in Dayabay Nuclear Power Station(GNPS) and Lingao Nuclear Power Station(LNPS), there are mainly two technical problems to solve in its RCM logic: failure consequence classification and maintenance tasks making. Failure consequence classification shows the different effects to enterprises after its failure modes. These show enterprises critical components and identification. RCM logic also shows the way how to determine a right maintenance requirement by different types of maintenance tasks selecting.

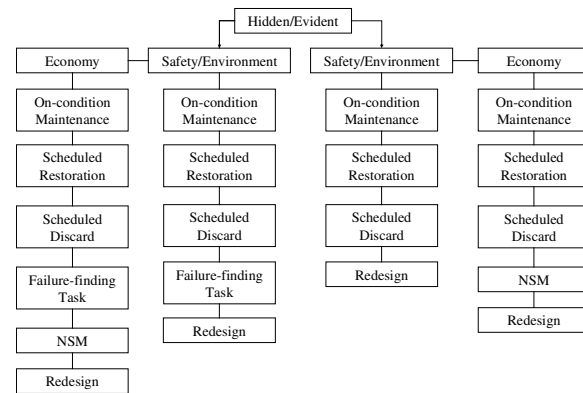


Figure 4: RCM Decision Making Logic Sketch

Figure 4 shows the simple logic diagram of GNPS and LNPS. From the RCM logic diagram, there are evident failure consequence, hidden failure consequence, safety consequence, environment consequence and economical consequence. In Logic decision making process, whether the failure mode being evident or hidden is the first question to answer according to the description of failure consequence. Then these information also helps to judge whether safety, environment, economy or not. There would be different task making for different types of failure consequence.

In decision making logic, all the maintenance types include on-condition maintenance, scheduled restoration, scheduled discard, failure-finding task, no scheduled maintenance and redesign. Maintenance task is made by its failure characteristic and consequence classification.

According to the interference and disturbance of maintenance task, there is a sequence for decision making: on-condition maintenance, scheduled restoration, scheduled discard. Then failure-finding task or no scheduled maintenance is considered, based on failure characteristic of evident and hidden consequence. For the equipment reliability, redesign task is the last choice in RCM logic. The theory analysis and practices from engineering show that redesign task is best choice only in no specific maintenance tasks meeting user's requirement.

No matter what maintenance task is made, not only the feasibility of task is considered, but also the economy of task implementation is considered and the failure risk is lowered to an acceptable level.

### 3.4 Developing Multiform RCM Training

Manufacturing enterprises want to introduce RCM. They not only need professional person familiar with RCM technique, but also need the understanding and supporting of RCM by all level personnel. Thus scientific approach and concepts can be put into use and absorbed in operation and maintenance. Therefore, different types of RCM training are necessary.

Generally new projects or new change will bring conflict to the old concepts. Education and training is the way from management field dealing with concept conflict. In order to reach good effect for the RCM project, different types of RCM training courses may be arranged.

- ❖ **Manager RCM training:** With the RCM introduced and spread, RCM introduction training to managers should be first considered. There are some new points and concepts in maintenance management in RCM. Some are different with traditional concepts. It is very important for the new project boosting by the RCM understanding of administration. Managers may get to know RCM background, its theory, concepts and analysis process by real data and examples. So the course may be arranged in 2 hours by a person with rich RCM work experience.
- ❖ **RCM knowledge and popularization training:** The course is set for spread and popularized to all the staff related to production, arranged half a day of RCM basic knowledge. Person from different departments are needed to participate and support the RCM process, so teamwork is necessary. After the popularization training, more personnel would understand RCM and give support, so as to high project efficiency.
- ❖ **RCM basic training:** It is one of the professional courses of RCM. It could be arranged for persons related directly to maintenance management or maintenance optimization. The content of this course includes RCM background, theory base, analysis process and so on. The course could be finished in 2-3 days according to content. Anyone who will take part in RCM analysis or who often make decision for maintenance strategy are suggested to attend the course.

- ❖ **RCM facilitator training:** This course is mainly for RCM facilitator. RCM facilitator is required for deep understanding of RCM, familiarization of the process and the whole approach. The course could be arranged by types of teaching and practice. After the cases and practice, the trainees could be more familiar with RCM approach. It would be helpful to new facilitators for dealing with real problems, cooperating with others and putting RCM result into use. Considering the effect and personnel, the course could be arranged by one to two weeks.

During the application of RCM, it is very important to have some qualified facilitators who do the maintenance optimization skillfully by RCM. A qualified facilitator needs comprehensive competence. And the facilitators are also the key persons RCM training for. What extent they understand and master would affect the actual effects of the RCM program as well as the expectation from the administration at the beginning of the program. So enterprises should focus on the cultivating and training of their qualified facilitators.

### 3.5 Setting up the Whole Flow Information Platform

There are lots of cooperation and interface associated with many departments in the implementation of RCM. And actually it is a strong technical process. Lots of information, documents and tasks would come into being in the process. It is necessary to set up an information system or maintenance task optimization system based on RCM analysis. The information from maintenance optimization to program implementation, program feed back is useful for validity and efficiency of maintenance activities.

After the RCM application, the final outcomes are the maintenance outlines which consist of lots of preventive maintenance (PM) tasks. These tasks will be carried out in daily or outage by station work request management system. The results of PM activities are fed back to the RCM analysis flow so as to correct the analysis gap. Then the PM activities are more pertinence and more suitable to meet the equipment condition and requirements. The following chart shows the relationship between RCM analysis information, maintenance outline system and work management system (fig. 5).

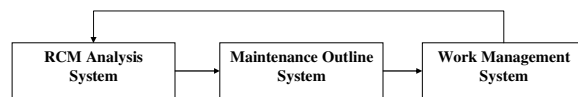


Figure 5: RCM System Interfaces with Other System

When setting up a whole flow information platform, results of RCM analysis, the management of the results and outline, the outcomes after PM checkups should be included. That is the three stages: maintenance strategy making, maintenance strategy management, maintenance strategy implementation. Fig.6 shows an example of maintenance process flow combined with station feature.

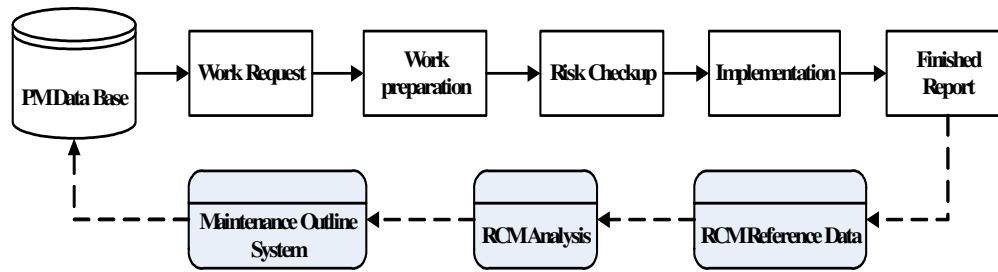


Figure 6: Maintenance Work Flow and External Interface

The fig.6 shows that there are interfaces between company maintenance work management, RCM analysis information system and maintenance outline optimization system. By the optimization for the interfaces, the sub-flow resource can be shared and the information flow would be simplified so as to enhance the whole flow efficiency. Otherwise, RCM analysis information is related to equipment reliability, so its technical outcomes are extensive and referenced, which interface could be spared for future ERP or other information system. For example, predictive maintenance system, abnormality management system and root cause analysis system can be set up relation and data exchange to share public resource.

#### 4 Conclusion

Enterprises are facing problems of maintenance management. Maintenance strategy decision making is one of the important issues in maintenance management. A successful and effective RCM program can improve equipment reliability and reduce maintenance expenses. GNPS and LNPS have finished over 120 systems RCM analysis. And the results are put into use, which enhance equipment reliability and availability as well as good control of maintenance cost. Take RCM system analysis in 2005 at GNPS for example, the estimation and calculation for the economy benefit of RCM application could save over \$3 million maintenance cost. With the progress of technology and the development of country economy, society has the higher expectation for equipment reliability and operation cost. Manufacturing enterprises could improve performance by application of RCM and its maintenance resource optimization. But due to the lack of extensive use and rich practice experience, manufacturing enterprises need to put more resources on organization, work flow, training, etc. in RCM application. Then it would exert more benefit of RCM technique.

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