UNIT 17 RELIABILITY CENTERED MAINTENANCE (RCM)

Objectives

After studying this unit, you should be able to:

- understand the concept of reliability centered maintenance,
- explain the importance of implementing RCM,
- know the methodology of implementing RCM,
- understand the benefits, pitfalls and misconceptions about RCM.

Structure

17.1 INTRODUCTION

Controlling maintenance costs, together with improving plant reliability and capacity has become an area of escalating attention in the ever increasing need to increase manufacturing competitiveness. A number of new maintenance philosophies have evolved and proven themselves in assisting maintenance managers in providing better plant utilization at lower cost. Amongst these are preventive maintenance, predictive maintenance, proactive maintenance, condition based maintenance and more recently reliability centered maintenance (RCM). A RCM strategy employs preventive, predictive and proactive maintenance technologies in an integrated manner to increase confidence that a machine will operate dependably over an extended life cycle. The integrated approach of various techniques is required, as no single technique is sufficient to accurately understand the problems of complex equipment. However, in combination, the various technologies provide a powerful set of capabilities of deriving a holistic picture of machine health. The ability to use the various techniques focussed around reliability affords an opportunity to move beyond fault detection towards developing a meaningful and valuable tool for a maintenance improvement program. The focus shifts on the elimination of machine failure, rather than the prediction of failures. Alongwith the preventive, predicted and proactive approaches, the RCM philosophy include knowledge based diagnostics of samples to incorporate a learning component within the program. The element of knowledge is permanently embedded within the working practices so that the organization does not repeat bad practices and make continuous error.

Activity 1

For your organization, prepare a comprehensive list of equipment/system/subsystem/part failures in the last one year and the maintenance practices like breakdown maintenance, preventive maintenance, predictive maintenance etc. used.

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17.2 HISTORICAL PERSPECTIVE OF MAINTENANCE PRACTICES

Over the last seven decades, the views about maintenance keep on changing. In early 1930s and 40s, generally called first generation maintenance practices, the practice was to 'fix it when it broke'; the term used was breakdown maintenance or corrective maintenance. In this period, the industry was not highly mechanized, equipment was simple and generally over-designed. This is tabulated in *Table 17.1*.

Table 17.1: Comparison of maintenance practices

Attributes	First Generation	Second Generation	Third Generation
Expectations	Fix it when it broke	— Higher plant availability — Longer equipment life — Lower costs	* Higher plant availability * Greater safety * Better product quality * No damage to the environment * Longer equipment life * Greater effectiveness
Techniques	Fix it when it broke	— System for planning and controlling work	* Condition monitoring * Design for reliability * Hazards studies * FMEA * FTA * Experts system
Models Maintenance	Corrective	- Preventive maintenance maintenance	* Total Productive * Reliability Centred Maintenance

The next generation called the second-generation spans from 1950s to mid of 1970s. The period witnessed increased mechanization, complex machines. The major concerns from maintenance were higher plant availability, longer equipment life and lower costs. The techniques of preventive maintenance were used considering failures follow bathtub curve theory.

In the third generation, with the advent of mechanization and automation, availability and reliability have assumed significant status. Alongwith this, the quality standards, safety, environment protection, longer equipment life are the other expectations of maintenance. Techniques like condition monitoring, expert system, design for reliability and maintainability, hazard studies, failure mode and effect analysis, fault

tree analysis took their position in the maintenance management.

17.3 CONCEPT OF RCM

RCM is a methodology as well as a philosophy, and it is not possible to define it with the help of one definition. The following definitions will help in understanding the concept of RCM.

RCM is a systematic approach for quantitatively assessing the need to perform or review preventive maintenance tasks and plans. It provides a methodology targeted on system functions, the failures relating to that function, and in particular to the effects of dominant functional system failures. A decision tree is used within RCM to identify and classify critical system components together with an appropriate and applicable maintenance policy. The main concept underlying the development of RCM is an attempt to retain the design reliability of equipment, through the analysis of factors which affect its operating reliability, and with a view to optimize preventive maintenance programs via effective maintenance planning.

RCM provides a structured and logical approach to determine the maintenance requirements of any physical asset in its operating context. The methodology helps in identifying what causes the functional failures of equipment and what are the consequences of any failure? RCM concept then recognizes that in true sense any maintenance is carried out, not so much to prevent the failures but to reduce the consequences of failures.

RCM approach takes in consideration that all equipment or components do not follow an age dominated failure mode and, therefore the maintenance requirements of all components cannot be evaluated in a similar manner. Thus RCM is a process used to determine the maintenance requirements of any physical asset in its operating context. A great strength of RCM is the way it provides simple precise and easily understood criteria for deciding which (if any) of the preventive tasks is technically feasible in any context, and if so for deciding how often they should be done and who should do them.

To summarize

- RCM is a process used to determine the maintenance requirements of any physical asset in its operating context.
- RCM is a process used to determine what must be done to ensure that any physical asset continues to fulfil its intended functions in its present operating context.
- RCM is a method for developing and selecting maintenance design alternatives based on safety, operational and economic criteria. It employs a system perspective in its analysis of system functions, failure of functions and prevention of these failures.
- RCM is a system consideration of system functions, the way function can fail and a priority based consideration of safety and economics that identifies applicable and effective PM tasks.

Thus RCM has four unique features:

1. Preserve functions
2. Identify failure modes that can affect functions
3. Prioritize function needs via failure modes
4. Select only applicable and effective tasks

17.4 RCM METHODOLOGY

The concept of RCM was developed in the early 1970s by the maintenance steering group of commercial airline industry in order to reduce maintenance downtime, maintenance cost and improve flight safety. It has also been successfully employed in grain terminals, coal mining, oil refinery, gas plants and paper industry. The methodology of the RCM is presented in the flow chart as shown in *Figure 17.1*.

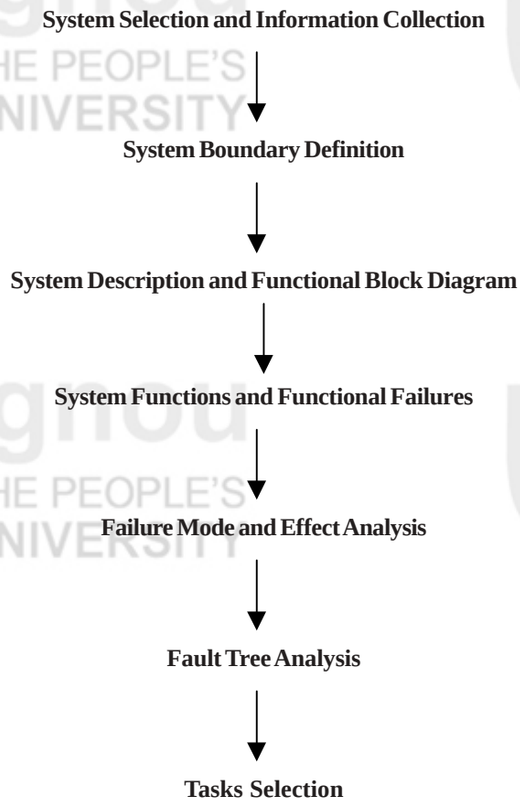

Figure 17.1: Flow diagram of RCM methodology

The various steps of the methodology are briefly discussed here.

1. ***System Selection and Information Collection:*** Various factors like large PM cost and actions, large corrective actions and cost, safety and environmental issues are considered for selection of system. Documents such as system schematics, equipment history files, vendor manuals, system operation manuals are need to be referred for collection of information.
2. ***System Boundary Definition:*** Major equipment included in the system are identified with primary physical boundaries. Defining of boundaries is required to make sure that the potentially important functions are not neglected and to establish the IN interfaces, factors coming into the system like power signals, flow heat etc. and OUT interfaces, factors that leave the system.
3. ***System Description and Functional Block Diagram:*** The various type of information developed in this phase are the following :
   i. Description of functions, redundancy and protection features
   ii. Hierarchy of functions
   iii. IN/OUT interfaces
   iv. Equipment list for each functional subsystem

v. Equipment failure history of past 2-3 years.

4. ***System Function and Function Failure:*** Function statements are developed for each functional subsystem by capturing every output interface. Functional failure statements focus on loss of function and not on equipment.

5. ***Failure Mode and Effect Analysis:*** In this step, the specific component failure modes — how the component must fail in order to produce functional failure — and the root cause for each failure mode are defined. Then the consequences of the failure mode are listed at three levels, locally at the level of component, at the system level and at the plant level. The primary reasons for conducting FMEA are to assure that the failure mode in question does in fact have a potential relationship to the functional failure being studied and to introduce initial screening of failure modes that are not detrimental.

FMEA technique was developed by the American defence industry in the 1960s to address the problems experienced with complex electronic weapon control systems. Subsequently it was extended for use with other electronic, electrical and mechanical equipment. FMEA can be performed in a variety of different ways depending on the objective of the assessment, the stage of equipment development and the information available on its components at the time of analysis. The FMEA focus may dictate a different worksheet format in each case; nevertheless, there are two basic approaches:

a) The Functional FMEA, which recognizes that each item is designed to perform a number of functions which can be classified as outputs. These outputs are identified and loss of essential inputs to the item or internal failures are then evaluated with respect to their effects on system operations.

b) The Hardware FMEA, which sequentially lists individual equipment items and analyses the effect of each item failure mode on the operation of the system. In many cases a combination of these two approaches is employed.

The FMEA worksheet is tabular in format to foster a systematic approach to analysis. The various columns of the table are:

- **Item Identity/Description:** A unique identification code and description of each item.
- **Function:** A brief description of the function performed by the item.
- **Failure Mode:** Each item failure mode is listed separately — there may be several for an item.
- **Possible Causes:** The likely causes of each failure mode.
- **Failure Detection Method:** Features of the design through which the failure is recognized.
- **Failure Effect:** The effect of the failure at the local level, system level and plant level.
- **Compensating Provisions:** Any internal compensating provisions which could mitigate the effect of the failure.
- **Remarks:** Comments on failure mode and effects, any recommendation etc.

Further columns can be added to the table to incorporate severity and frequency of failure, probability of failure effect, data source etc.

Activity B

For any equipment or process in your organization, perform the Failure Mode and Effect Analysis.

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6. ***Fault Tree Analysis/Logic Tree Analysis:*** There are two approaches that can be used to analyze the causal relationships between component failures and system failure. These are inductive or forward analysis and deductive or backward analysis. FMEA is an example of inductive analysis, it starts with a set of component failure conditions and proceeds forward, identifying the possible consequences. This is a 'what happen if' approach. Fault tree analysis is a deductive 'what can cause this' approach and is used to identify the causal relationship leading to a specific system failure mode– the top level.

The fault tree is developed from this top, unwanted event, in branches showing the different event paths. Component failure events represented in the tree are progressively redefined in terms of lower resolution event until the basic events on which a good quality failure data are available.are encountered. The events are combined logically by use of gate symbols, which shows the structure of a fault tree. Using the fault tree analysis, the probability of the top event or the top event frequency can be calculated by providing the information on the basic event probabilities.

7. ***Task Selection:*** The RCM process require that each task selected must satisfy the applicable and effective test, which are defined as follows:

   Applicable: The task will prevent or mitigate failure, detect onset of a failure or discover a hidden failure.

   Effective: The task is most cost effective option.

In RCM tasks are designed to prevent three types of failures:

a) Dangerous failures injurious to the public, employees or to the environment, such as boiler safety valve, or the rupture of a tank of volatile chemicals. Example of Bhopal gas leak is an example of this type of failure.

b) Expensive failures where the consequences are operational downtime and large breakdowns such as loss of cooling water to a data center or breakage of the chain in an auto assembly line. The breakdown of power transmission is an example of this type of failure.

c) Frequent failures that happen continually and are disruptive to the work environment resulting in high repair cost. Frequent breakdown of buses of a transport company is an example of this type.

Under RCM, the problem is not failure at all, it is the consequences of failure.

Identification of Critical Parts and Tasks

The identification of critical parts of equipment and preparing the task list is the heart of the RCM system. This list represents the accumulated knowledge of the manufacturer, skilled mechanics, engineers, contractors, insurance companies, trade associations, equipment distributors and consultants. The list reminds the management what task to do, who has to do it, what parameters to look into, how to do it and when to do it. The task list can be divided into two categories:

Category 1: The list of tasks that help to extend the life of an equipment or increase the mean time between failure. The examples of this category are clean the machine, lubricate, tighten the screws, secure any loose guards, replace a worn out component etc.

Category 2: This list of tasks detects when the equipment has begun its descent into breakdown. The examples are routine inspection, measurement of parameters, taking samples for analysis, review of the history of machine, interview of the operator and others tools of condition

The following issues should be considered while preparing the task list.

a) **Complete description of the task:** The task should be completely, unambiguously described, preferably with the help of drawings. Any precaution to be taken while doing the task or the risk of release of gases, possible spillage etc. should be outlined.

b) **Planning aspects of the task:** Performance characteristics and specification about the task should be recommended. Skill level needed, any special license required, special tool required, parts needed, value of the parts, total cost of the task, tasks to be subcontracted should be specified.

c) **Operational aspects of the task:** The planned frequency (clock days, utilization, condition), time required to perform the task, involvement of other departments, impact on other departments and any notification required is to be specified in the task list.

Types of Task List: The listing of tasks can be done on the basis of unit, string, future benefits or condition based. Each method has its own merit and demerit. The selection of a method is situation specific and at many instances a combination of two or more methods are used.

Unit base task list: This is the most popular type of task list, where one machine or equipment is taken as a unit and all the tasks are completed on one unit before going on to the next unit. Short repairs also carried out by the mechanic with the tools and material carried by him. For large size systems like utilities, sometime several people from different sections converge at the same point to perform their task list. This type is called gang based. The advantages of unit based task list is that it is more effective, the mechanic gets to see the big picture. Person learns the machine well and has ownership. The disadvantage is a skilled mechanic with high training is required.

String based task list: This list has few items on many units in a string. Lubrication route is an example of string based system. This is an efficient method since a worker would be focused on only one activity. The advantages are: task can be performed by less skilled worker, requires lower training and have high productivity. The disadvantages of the method are loss of big picture about a machine, monotony of job, no ownership and difficult to supervise.

Future benefits: This type of task list is generally considered in the chemical plants, petroleum and other process industries where the processes are closely coupled. A breakdown or changeover at one place makes the whole system idle. In this the task list of the whole train is carried out whenever a breakdown or changeover took place. The advantages are little or no extra down time, easier to manage, and can be exciting. The only disadvantage is a large size team is required.

Condition based task list: This list is prepared based on some readings or measurements going beyond a predetermined limit. The method has high probability that some intervention is needed, involves the operator, brings maintenance close to production, supports quality programs. The disadvantage is that it requires a skilled manpower and some time may be too late to avoid breakdown.

Activity C

With respect to your organization, find out the applicability of RCM. Identify an equipment or process for RCM and prepare the task list.

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17.5 BENEFITS OF IMPLEMENTING RCM

RCM focus is on system function approach. Complex redundant systems have reliability directly engineered into their design. The reliability of a system is reduced if maintenance tasks and frequencies are not its integral component. Over maintenance reduces the system reliability on account of maintenance induced failures. For highly reliable system, reliability very often is reduced due to human intervention under the pretext of PM. Therefore, RCM methodology has been successful in building up highly reliable systems. RCM methodology helps in achieving the following:

- High quality, cost effective maintenance plans in less time
- Assurance that all maintenance important parts and their failure mode are critically considered in the development of maintenance programs
- Increased probability that the level and content of the maintenance requirement is optimally specified
- Provides the basis for routine, on-line information sharing among engineering, operations and maintenance staff
- Longer useful life of expensive assets
- Improved safety of equipment and plant personnel
- Better environment protection
- Improved operating performance in terms of output, quality and customer service

17.6 MISCONCEPTIONS ABOUT RCM

1 ***RCM will eliminate breakdown:*** RCM can only help in reducing the number of breakdowns and their severity and consequences.

2 ***RCM is a way of replacing/attending a part before it breaks:*** RCM is much bigger than that. It is an integrated approach to budgeting, failure analysis, eliminating excessive resource use and permanent correction of problem area.

3 ***All the RCM systems are same and can be copied:*** RCM systems are tailor made, designed to keeping in view the type of equipment, age of equipment, product manufactured, type of service, severity of usage, skills of the operator etc.

4 ***RCM increases the workload and expenses:*** RCM increases uptime, reduces energy usage, reduces unplanned events etc. Only in the beginning a good planning is required.

5 ***Unskilled workers can perform RCM:*** With good procedures and training, unskilled workers can do many routine tasks. For greater return on investment, skilled people must be in the loop.

17.7 PITFALLS IN IMPLEMENTING RCM

Most of the organizations try a small project in one place or another, but they have no real organized or structured approach to RCM. The common problems leading to the lack of success with RCM can be summarized as follows:

a) **Insufficient Equipment Failure Data**
Historical data about equipment failure is required for the RCM program to be effective. Without the data about the failure, frequency of failure and root cause of the failures, the RCM programs are based on guesswork. RCM is an advanced technique that is used only when effective preventive and predictive programs are in place.

b) **Poor Training in the RCM Methodology**
RCM has a structured and logical approach. It doesn't allow an individual to do things in unplanned way. RCM consists of many methodologies, some have flexibility, whereas others are more rigid. Some require lot of data, others less. Some approaches are more successful in one industry than other. Thus after selection of the appropriate approach, all the employees involved in RCM efforts should be trained to a high degree of proficiency in the appropriate RCM techniques. Without the training, the RCM efforts will never achieve maximum benefits for the organization.

c) **Poor Results in the PM and PDM Efforts**
The PM programs have the goal of reducing the reactive maintenance activities to less than 20 percent of all the maintenance work. The PDM programs have the goal of eliminating all unplanned breakdowns. If these two programs are not producing results, the company should not attempt to RCM.

d) **Lack of Understanding at Top Management Level**
The lack of understanding about the benefits that can be achieved from a successful RCM program results in poor support from top management. While presenting the concept of RCM to upper management, present the case in terms of cost benefit analysis or return on investment, instead of MTBF and MTTR. Also present the opportunities by highlighting the current losses, amount of losses that can be reduced and cost of RCM program etc.

e) **Insufficient Staffing for the Program**
RCM task is in addition to maintenance activities and thus required additional funding for tools and personnel. Company should provide the required staff for the success of and getting full benefits of RCM program.

f) **Short Term RCM Efforts**
RCM is a valuable tool, especially when coupled with a disciplined maintenance improvement program. It has the capacity to take the organization from reactive to world class maintenance. The journey takes 5-10 years with no successful short cuts.

g) **Lack of Focus**
The organization need to be focussed on its vision, the improvement plan and the implementation methodology needed to achieve the goals.

h) **Short Term Equipment Focus**
The understanding of the true life cycle of the equipment and related components

is necessary to make the equipment last longer and perform better. Companies willing to useup, wear out or accept sub-standard performance from their equipment will not survive in today's competitive environment.

17.8 SUMMARY

RCM is a methodology aimed at mitigating the impact of equipment failures by having an enhanced understanding of how the asset works, what it can and cannot achieve. By knowing the failure mode and root causes, the efforts of maintenance are rightly focused to solve the fundamental problems and thereby enhancing the reliability of equipment or process.

In this unit, you studied the concept of RCM, why we should implement it. A detailed methodology is presented, by following which you can implement RCM in your organization. If implemented in the manner suggested in the unit, organization will be benefited in terms of improved operating performance of the assets and greater cost effectiveness in maintenance.

17.9 SELF ASSESSMENT QUESTIONS

1. Discuss as how RCM can be helpful to maintenance manager in improving his job functioning?

2. "A well knit preventive and proactive maintenance is a prerequisite for implementing RCM". Discuss.

3. "RCM methodology focuses on the maintenance of functions rather than the equipment per se". Comment.

4. "Under RCM methodology, the problem is not failure at all, it is the consequences of failure". Discuss.

17.10 FURTHER READINGS

1. Agarwal, V.K. and Gandhi, O. P., "*Reliability Centered Maintenance*", Proceedings of SERC School on RAM, April 14-25, pp145-152, IIT Delhi, 1997,

2. Anderson, R. T. and Lewis, N., "*Reliability Centered Maintenance Management and Engineering Methods*", McGraw Hill, 1990.

3. Maubray, J., "*Reliability Centered Maintenance*", Butterworth Heinemann, Oxford, 1991.

4. Rausand, M., "*Reliability Centered Maintenance*", Reliability Engineering and System Safety, Vol. 60, pp121-132, 1998.