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RCM–based maintenance plans for different operational conditions

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BSc Programmes in Engineering
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” Learning starts with failure;
the first failure
is the beginning of education”

John Hersey

Abstract

RCM is a maintenance method, which comes from the airline industry, in the late 1970's. The method is used to control the maintenance, prevent possible failures and make the maintenance done in an appropriate frequency. To achieve the RCM analysis a RCM team must be created.

When implement the RCM method in other customer operational conditions, the method must be the same for fulfil the SAE maintenance standard. Instead must the implementation process be modificated.

This thesis work has been performed at Metso Paper, Service Inc., in Sundsvall. Metso Paper is interested in the RCM process and how it could be used in other customer operational conditions.

The purpose with this thesis report was to define what the RCM method is, try to find suggestions of how to implement the RCM method into other customer operational conditions. There was also pilot project done on a twin wire press, to really se how the RCM analysis was performed.

The pilot project were limited to five sub-systems of the twin wire press. These sub-system have been gone through a total RCM analysis, to the front of the audit process.

To successfully implement the RCM method into other customer operational conditions and in their maintenance organizations, must a very good understanding about their culture be made. Also must the implementation process be planned clearly, so that the best result will be reached.

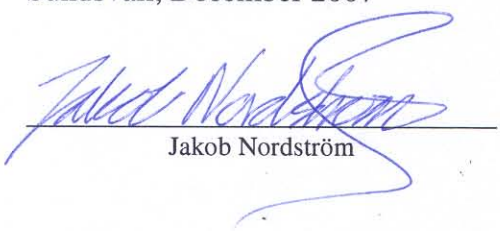
Preface

The work presented in this thesis was carried out at Metso Paper, Service Inc. in Sundsvall and it's the final moment in the Bachlor's degree in Aeronautical engineering with concentration to operation and maintenance. The company supervisor at Metso Paper, Service has been Lars Olsén and examiner at Luleå University of Technology has been University associate Professor, PhD, Aditya Parida. The RCM/FMEA workgroup have consisted of the following people: Henrik Bergström, Staffan Edström and Johan Fällman.

I would like to thanks everyone that have been adjuvant durig my thesis work. Without the ideas and support from you, this work should have been impossible to conduct.

A special thanks goes to my examiner Aditya Parida and the company supervisor Lars Olsén. Who have supported, taken time and exchanged ideas with me. This have been very valuable for me and the progress of my work.

Sundsvall, December 2007



Jakob Nordström

Acronyms and Abbreviations

B747	Boeing 747 jumbo jet airliner
CMMS	Computerized Maintenance Management System
DC-8	McDonnell Douglas aircraft, (“Douglas Commercial – 8)
DC-10	McDonnell Douglas aircraft, (“Douglas Commercial – 10)
DoD	Department of Defense
FAA	Federal Aviation Administration
FalconView™	Metso Paper, condition monitoring equippment
FMEA	Failure Mode & Effect Analysis
FMECA	Failure Mode, Effects & Criticality Analysis
JT9D	Pratt & Whitney engine to B747
L1011	Lockheed 1011 Tristar airliner
Mill	Factory or a plant
MSG 1-3	Maintenance Steering Group 1-3
NASA	National Aeronautics and Space Administration
PRN	Probability and Risk Number
TC	Type Certification
TMP	Thermo-Mechanical Pulp
TWP	Twin Wire Press
USAF	United States AirForce

List of enclosures

Enclosure 1 Time schedule
Enclosure 2 RCM spreadsheet
Enclosure 3 RCM spreadsheet
Enclosure 4 RCM logic tree
Enclosure 5 RCM logic tree
Enclosure 6 Factory layout
Enclosure 7 Implementing plan for success.

List of figures

Figure 1. Maintenance development process.
Figure 2. Different kind of failure patterns
Figure 3. Ideal RCM team composition
Figure 4. The RCM process
Figure 5. Different maintenance methods
Figure 6 The twin wire press
Figure 7. Pulp process through the TWP.
Figure 8 Sub process of the TWP.
Figure 9. Twin Wire Press systems
Figure 10. Different culture levels
Figure 11. Learning process of organizations

TABLE OF CONTENTS

1. INTRODUCTION 4

1.1 BACKGROUND 4
1.2 AIM 4
1.3 OBJECTIVE 4
1.4 SCOPE AND LIMITATIONS 5

2. METHOD 6

2.1 WORK PROCESS 6
2.2 LITERATURE STUDY AND THEORETICAL CONCEPT 6
2.3 PERFORMING THE RCM ANALYSIS 6

3. BACKGROUND OF MAINTENANCE 8

3.1 THE FIRST GENERATION 8
3.2 THE SECOND GENERATION 8
3.3 THE THIRD GENERATION 9
3.3.1 NEW EXPECTATIONS 9
3.3.2 NEW RESEARCH 9
3.3.3 NEW TECHNIQUES 10

4. RCM 11

4.1 RCM DEFINITIONS 11
4.2 BACKGROUND OF THE RCM METHOD 12
4.3 RCM SEVEN QUESTIONS 13
4.4 SET LEVEL OF ANALYZE 14
4.5 CREATE A COMPONENT LIST 14
4.6 ORGANIZE A RCM TEAM 14
4.6.1 THE LEADER OF THE RCM TEAM 15
4.7 RCM ANALYSIS 15
4.8 FMEA IN THE RCM METHOD 15
4.7.1 THE BACKGROUND OF FMEA 15
4.9 INFORMATION ABOUT RCM 7 STEPS 16
4.9.1 FUNCTION 16
4.9.2 FUNCTIONAL FAILURE 16
4.9.3 FAILURE MODE 16
4.9.4 FAILURE EFFECTS 16
4.9.5 FAILURE CONSEQUENCES 17
4.9.6 THE RCM TASK SELECTION PROCESS 17
4.9.7 DEFAULT ACTIONS 18
4.9.7.1 Failure finding 18
4.9.7.2 Redesign 18
4.9.7.3 No scheduled maintenance 18
4.10 THE RCM AUDIT PROCESS 18

4.11 THE RCM PROCESS **19**
4.13 MODIFIED RCM METHODS **20**
4.13.1 THE PMO METHOD 20
4.14 MAINTENANCE METHODS **20**
4.14.1 CORRECTIVE MAINTENANCE 20

5. THE PILOT PROJECT **22**

5.1 THE TWIN WIRE PRESS **22**
5.2 THE BACKGROUND ABOUT TWP **22**
5.3 THE PULP FLOW INTO THE TWP **22**
5.4 THE FUNCTIONS OF THE TWP-SYSTEM **23**
5.4.1 THE PARAFORMER 23
5.4.2 THE WIRE 23
5.4.3.THE PRESS TABLE 23
5.4.4 THE PRESS SECTION 23
5.4.5 THE DRIVE ROLLS 23
5.4.6 THE SHREDDER SCREW 23
5.4.7 THE HYDRAULIC SYSTEM 24
5.5 SOME SUB-FUNCTIONS OF THE TWP **24**
5.5.1 THE DOCTOR SYSTEM 24
5.5.2 THE SHOWER SYSTEM 24
5.5.3 THE WIRE TRACKING SYSTEM 24
5.6 THE TWP ANALYZED SYSTEMS **24**

6. FACTORY LAYOUT OF A TMP MILL **25**

7. DESCRIPTION OF TODAY'S MAINTENANCE **26**

8. DIFFERENT CUSTOMER'S OPERATIONAL CONDITIONS **28**

8.1 THE RCM IMPLEMENTATION PROCESS **28**
8.1.1 THE TASK FORCE APPROACH 28
8.1.2 THE SELECTIVE APPROACH 29
8.1.3 THE COMPREHENSIVE APPROACH 29
8.2 DIFFERENT CULTURES **30**
8.3 PLANNED CHANGE **31**
8.4 ORGANIZATIONAL LEARNING **32**
8.5 COMMUNICATION **33**
8.7 CMMS **34**
8.7 AGREEMENTS **34**

9. DATA COLLECTION AND ANALYSIS **35**

10. DISCUSSION **36**

11. THE ACHIEVEMENT OF THIS THESIS 36

12. CONCLUSIONS AND RECOMMENDATION FOR FURTHER WORK..... 37

13. REFERENCES 39

1. Introduction

In this chapter the background, aim, objective, scope and limitations are described

1.1 Background

The Metso Corporation is one of the worlds leading producer of technology in three different branches: paper, mineral and automation. Metso Corporation is offering total equipment solutions for both the paper-, rock and minerals industry.

Metso Paper is a pulp and paper technology company based in Sundsvall. Metso Paper is a part of the Finnish owned Metso Corporation. The Metso plant in Sundsvall has got experience in several business areas such as; construction, development, sales, production, and service for both chemical and mechanical pulp technology.

Metso Paper's maintenance department in Sundsvall, is specialized in all type of service regarding pulp, paper and bale industry. That includes service of the equipment both at Metso customers Mill's and also, some overhauls in the maintenance workshop, in Sundsvall. The maintenance workshop in Sundsvall, have both planned maintenance of equipment and they also, perform emergency overhauls of equipment, from customer's Mill.

Several companies in the Metso Corporation have made studies about the RCM method. Earlier this year, Metso Paper performed some introduction meetings about how to progress with RCM method. Also, many of Metso's customers strive against the use of preventive maintenance, such as; the RCM method. Therefore, the Metso organization have the ability to offer RCM based maintenance plans.

1.2 Aim

The aim of this work is to define what the RCM process is about, through a small pilot project on a twin wire press and at the same time come up with some ideas of how to solve the use of the RCM method in other customer's operational conditions.

1.3 Objective

The objectives are to increase the knowledge about the RCM method in general, compare the existing maintenance with the maintenance suggestions from the RCM analysis and at the same time, see if, there are any solutions of how to use the RCM method into other customer's operational conditions

1.4 Scope and limitations

When performing the pilot project of the twin wire press system with the RCM methodology, some limitations needed to be considered due to time constraints, which are as follows:

- The RCM analysis will be carried out at a system level.
- Only five subsystems will be analyzed on the twin wire press
- There will be no implementation work for the pilot project, in Metso's current maintenance system.

The five subsystems chosen, have been due to high failure rate and caused decreased production rate, in some cases.

2. Method

In this chapter, all the methods that have been used will be presented.

2.1 Work process

To complete the thesis work with a very limited timeframe, the work needs to be well structured. Therefore, a time schedule was made;

- Literature study
- RCM analysis
- Interviews with Metso staff
- Present maintenance process at Metso
- The use of the RCM method in other customer's operational conditions
- Report writing

The detailed time schedule can be seen at enclosure 1.

2.2 Literature study and theoretical concept

The thesis work began with a literature study, to enhance the understanding of the knowledge further about the RCM process. After that, a detailed study was performed to the TWP system, to understand its overall function and also, how each sub-system of it worked.

There was also a literature study performed about how to use the RCM method in customer's organizations with no similar operational maintenance conditions.

2.3 Performing the RCM analysis

The TWP system was broken down in to several sub-systems. These sub-systems were scrutinized through a selection process, where the system with the highest failure rates and complexity were chosen. The systems selected were; the paraformer, the press section, the drive rolls, the hydraulics and the wires.

The analysis process started with a selection of Metso staff, who had great experience from the TWP system. Due to time constraints and the fact that the analysis process shouldn't interfere with the normal workload, it was decided to interview the staff one by one, instead of having them all gathered at once. The analysis part was conducted in several meetings, and the staff were experts on their sub-system. Because the interview was selected instead of gathering the whole RCM group, some back checking were undertaken to receive the best result.

At the start of each interview, an briefing about the RCM method was conducted. With a common knowledge about the method, a better result is achieved and also the engagement of the analysis group was higher.

The RCM analysis was performed according to the SAE standard (JA1011) and there by fulfilling the RCM's basic seven questions.

These are the basic seven questions of the RCM method:

1. What are the functions and associated performance standards of the asset in its present operating context?

2. In what way does it fail to fulfil its functions?

3. What causes each functional failure?

4. What happens when each failure occurs?

5. In what way does each failure matter?

6. What can be done to predict or prevent each failure?

7. What should be done, if a suitable proactive task cannot be found?

3. Background of maintenance

The maintenance has increased rapidly in complexity, over the last 70 years. With that, in consideration, new maintenance methods and maintenance ways have been developed. In general, the maintenance has developed through three different phases, generating from 1930s.

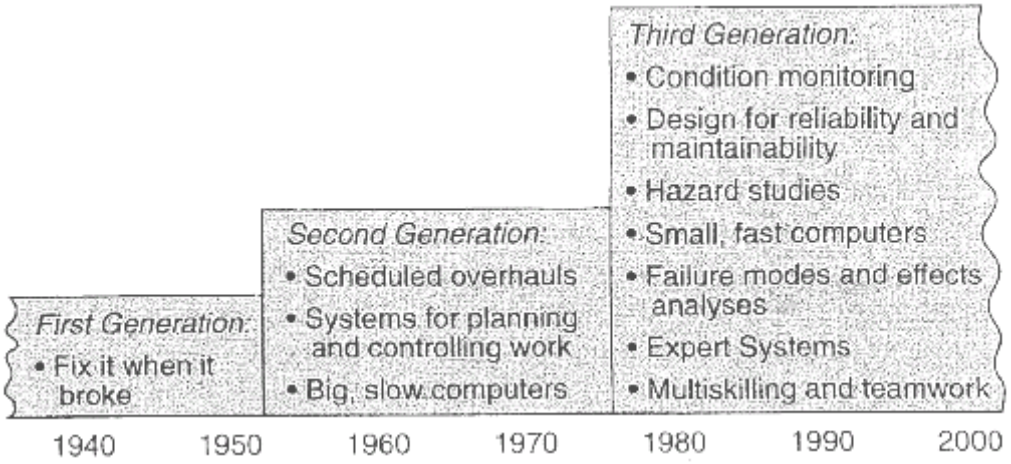


Figure 1 Maintenance development process. [1]

3.1 The first generation

The first generation of maintenance starts approximately around 1930 and ends somewhere around 1950. During that time, the complexity of the industrial systems was quite low. At the same time, many of the mechanical systems were over-designed. This lead to the fact that the systems were quite simple, and therefore were easy to maintain, for the maintenance personal. Due to the fact that the systems were relatively simple, the use of preventive maintenance was also low. [1], [3]

3.2 The second generation

The second generation of maintenance started around the Second World War. During the wartime, the industries that are connected to the war brought the technology to a higher level. Therefore, the mechanical systems are increased in both complexity and in size.

At the same time, the industry became more interested in how to decrease downtime in their factories. To decrease downtime, the functional failures of the machines must be known and prevented. Therefore, the old ways of over-designing the whole system have stopped, and the maintenance organizations began to use preventive maintenance instead of only corrective maintenance.

Around 1960's, the maintenance were almost only preventive maintenance, with fixed intervals and overhauls. This led to higher maintenance cost in comparison to the operational costs. The industrial managers started to look for new ways to minimize maintenance costs and maximize the lifetime of their equipment. [1],[3]

3.3 The third generation

The third generation of maintenance starts in the middle of 1970's. The third generation of maintenance leads until today's maintenance and are therefore divided into three subchapters, new expectations, new research and new techniques. [1], [3]

3.3.1 New expectations

The 1960's and 1970's downtime made the life hard for the manufacturing industry, as it affected them all in a negative way. Therefore operational safeties have grown to a key issue, so that the performing systems strive to have a high reliability and availability. That's because time is money, and when a factory is suffering from an unplanned stop, the costs are rising very quickly. In today's industry, the cost are rising above all, especially the maintenance cost. In some industries today, maintenance cost is the second highest or highest cost for the plant. Over a time of thirty years, maintenance costs have moved from the bottom to the top, due to more complex systems.

3.3.2 New research

Some new researches have proved that many of the old beliefs about how equipment fails are wrong. The researchers have come to the conclusion that the lifetime of equipment aren't linked to their operational lifetime, in the way of their likely hood to fail. The RCM method have six failure patterns, half of them are time related. See all the failure patterns below

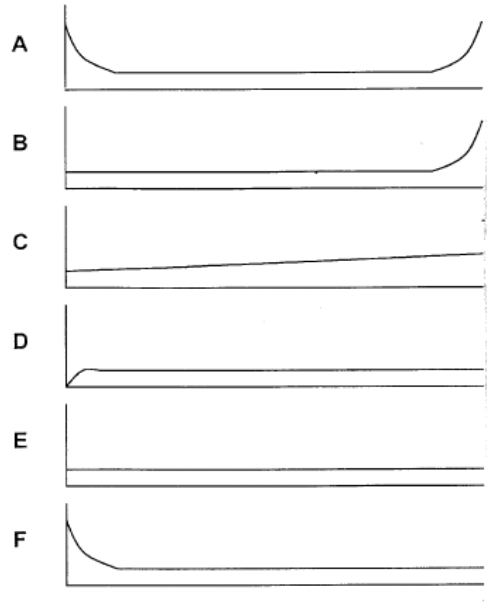


Figure 2 Different kind of failure patterns

The first three curves (A-C) are time related and therefore the rest (D-F) are not time related. Curve A, is from the second generation of maintenance and represent a high infant mortality followed by a constant failure rate and then at the end a high wear out region will follow. Curve B, is from the first generation of maintenance and represent

a constant or gradually increasing failure probability followed by a drastic wear out region, which could lead to failure. Curves C to F are from the third generation of maintenance. Curve C; represent a gradually increasing failure probability rate, with no wear out region. Curve D; represent a low failure probability when an item is new and then a quick raise followed by a constant rate. Curve E, represent a constant probability at all ages Curve F, represent a high infant mortality followed by a quick decrease to a constant or a very slow increasing failure rate. [1], [3] & [7]

3.3.3 New techniques

Since the late 1970's there has been a tremendous growth of new maintenance techniques. Several hundred of different methods have been born and the creation of new methods continues. [1]

4. RCM

The acronym RCM stands for Reliability Centered Maintenance and is a maintenance method.

4.1 RCM definitions

From the birth of the RCM method, many authors have made several different definitions of what the RCM concept stands for, here are some examples:

"Reliability is the probability that a device will satisfactorily perform a specified function for a specified period of time under given operating conditions."

Definition by author Anthony M. Smith [3]

"Reliability centered maintenance: a process used to determine what must be done to ensure that any physical asset continues to do what its users want it to do in its present operating context."

Definition by author J. Moubray [1]

"A systematic method to quantitively estimate the need to perform or update preventive maintenance effort and procedures on safety basis and economical consequences"

Definition by author Uday Kumar [5]

All of these definitions by different authors have something in common regarding the definition of the RCM method

- Preservation of the functions in the system, so that it function according to the user.
- The method have strict guidelines to estimate the need for maintenance tasks

4.2 Background of the RCM method

In the late 1960's, a new generation of aircrafts were born, the Boeing/jumbo jets. With this new generation of aircrafts a more modern way of maintenance was needed. The largest airliner at that time had just been manufactured and it was the Boeing 747 airliner. The B747 had no other counterpart; it could take three times as many passengers as the B707 and the DC-8. The number of passengers were not the only thing that were different, the mechanical technology was very highly developed, and also the avionic systems. The aircraft was also fitted with four brand new Pratt & Whitney, JT9D engines.

At the same time, the Federal Aviation Authority (FAA) which is the regulating authority of the American aviation industry became thoughtful of how to maintain the new airliner. Because, every new aircraft must be licensed by the civil aviation authority, such as the FAA, the licensed process in the aviation industry is called "Type Certification (TC)". The TC handles each aircraft type design, operation limitations, many different regulations that concerns the specific aircraft and also how the operators should maintain the aircraft. The preventive maintenance plan should be approved by the FAA to get the TC documentation. Without a TC the aircraft wouldn't be allowed to fly.

The FAA came in to conclusion that the usage of preventive maintenance on the B747 would be very extensive, so extensive that no airline in the world could have the capability or the money to operate it. Due to that conclusion by the FAA, all the larger airlines started to conduct a revision of the preventive maintenance strategy. The leading airline company of the revision, the United Airlines had re-worked a new preventive maintenance strategy. Some of the engineers that had been working with the revision were Stan Nowland and Howard Heap, they later became famous for their new "RCM" tool. The result of the United Airline work was a decision tree diagram of how to rank the preventive maintenance tasks and also how to preserve critical aircraft items during flight. The first documentation from the United Airlines were the "Handbook: Maintenance Evolution Program Development", generally known as the MSG-1. The new maintenance program developed from MSG was a success, and made it able for the airline companies to operate with B747.

Some improvements of the decision tree diagram lead in 1970's into a new document that was called: "Airline/Manufacturer Maintenance Program Planning Document", which later became known as MSG-2. The MSG-2 strategy was used to develop maintenance programs for L1011, the DC-10 airliner and many other civilian airliners all over the world.

In 1972, the Department of Defense (DoD) applied the MSG-2 ideas to their military aircraft fleet with the military aircraft P-3 and S-3. Later also the well known F-4J aircraft had the MSG-2 strategy implemented. During the years 1974-78, DoD work with the United Airlines to improve the MSG method. Because United Airlines worked as a contractor for the DoD, the DoD decided that the name MSG should be changed to Reliability Centered Maintenance, (RCM). In 1978, United Airlines released the guidance document that became the "RCM bible". The authors to the "RCM bible" were Stan Nowlan and Howard Heap.

Since then, the whole US military have implemented the RCM strategy on all of their aircrafts. They have also implemented the RCM strategy into their major weapons systems.

In the early 1980's, some more improvements had been carried out and therefore, a third document was invented. The document was called Operator/Manufacturer Scheduled Maintenance Development, and known under the name MSG-3. The basic change between MSG-2 and MSG-3 was the change of the decision logic. The MSG-3 strategy is still in use among the airline operators today.

Since 1980, the RCM methods have been implemented into several different industrial areas e.g. power plants, electronic Mills, paper and pulp Mills. [1-3], [5-6]

4.3 RCM seven questions

The RCM method have got seven basic questions that must be fulfilled, in order to determine if it is a true RCM method. That's due to the fact that the RCM method is a SAE standard (JA1011-12). The seven questions are listed below: [1]

- What are the functions and associated performance standards of the asset in its present operating context?
- In what way does it fail to fulfil its functions?
- What causes each functional failure?
- What happens when each failure occurs?
- In what way does each failure matter?
- What can be done to predict or prevent each failure?
- What should be done if a suitable proactive task cannot be found?

4.4 Set level of analyze

When the decisions have been made that a RCM analysis should be done, there are two questions that must be answered:

- At what level should the RCM method be conducted?
- Should the whole plant/Mill be analyzed, if not, how are selections made?

The RCM method can be conducted in general, into three different levels. These three levels are: plant, system, and component. [2] & [4]

4.5 Create a component list

After taken the decision of what to analyze, a component list should be done. The list consists of basic aid to the RCM analysis. The basic aid can consist of information about the selected system, drawings, pictures, schedules of pipes or electric components. The component list could both be formal or informal, depending on the situation. [1] & [3]

4.6 Organize a RCM team

Before the RCM analysis can start, a RCM workgroup must be arranged. The personnel that are included in the RCM team should be experts on its own field of view. The composition of the group should, if it's possible consists of members from different areas of the facility. By having a composition of many different personal a truer picture can be made for the analysis. If the RCM method is taking place in a Mill/factory the ideal composition would be as shown below: [1] & [3]

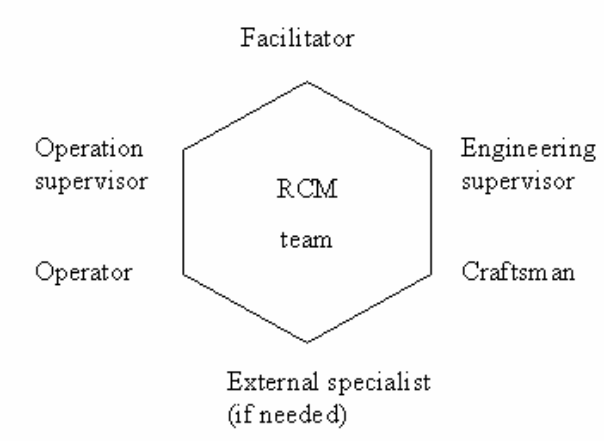


Figure 3 Ideal RCM team compositions [1]

4.6.1 The leader of the RCM team
The RCM team must have a leader, to perform and achieve RCM as good as possible. The leader's responsibilities are to:

- Ensure that the RCM analysis is performed at the right level and that the system boundaries are well defined.
- Ensure that the RCM method is correctly understood among the RCM team.
- Document the result in a proper manner.
- Ensure that the analyses on the selected system are well planned.
- Ensure that no vital parts are left and forgotten.
- Keep the analyze in the assigned timeframe

4.7 RCM analysis

The FMEA method replies of the first 4 questions of the RCM analysis.

The seven basic RCM questions that the FMEA method replies to are as follows:

- What are the functions and associated performance standards of the asset in its present operating context?
- In what way does it fail to fulfil its functions?
- What causes each failure?
- What happens when each failure occurs?

4.8 FMEA in the RCM method

The FMEA method is a quality improvement tool that have got its root's in the aviation industry. The acronym FMEA stands for Failure Mode & Effect Analysis.

4.7.1 The background of FMEA
After the second World War, the USAF needed to improve the reliability on their aircraft fleet. The overall technical development proceeded very rapidly and many high sophisticated machines were produced, many in the aviation industry. Therefore, in late 1949 they created a new method by the name FMEA. During the years 1950-1960, Boeing aircraft company developed the method further and became the "real" creator of the FMEA method.

The basic concept of the FMEA method is based on a systematic way of analyzes a system or a construction of a product. During the systematic analysis of the system some data were registered, such as failure modes, failure effects and failure consequences. Boeing Aircraft Company was the first real company to use the basic FMEA method. Later NASA extended the basic approach of FMEA and applied a critical analysis to the basic FMEA approach. The critical analysis is a tool to ensure the reliability in a system.

In the 1960's, NASA used the FMEA method in the Apollo space programs (1963-1972). Later, in the 1970's, the FMEA method came in to general use as a quality improvement tool. The use of the method spread at first to the car industry with Ford Motor company in the lead and then later to other industrial areas. [23]

The use of the FMEA method came to Sweden around 1980 and have since then been spread to practically every industrial area. At first the method was implemented into Swedish armed forces and into nuclear power plants.

There are numerous reasons why the uses of the FMEA method have increased.

- Demands on quality improvements due to higher quality concerns from the customers.
- Increased competition regarding price and quality.
- Increased complexity of the products.
- The ambition of decreasing lead time.

4.9 Information about RCM 7 steps

The RCM method consists of seven basic questions, as mentioned previously. Under the following sub-chapters the different steps of the RCM method will be explained. All of these steps are documented in a RCM spreadsheet document, which can be seen in enclosure 2 and 3. [1] & [3]

4.9.1 Function

The first step of the RCM analysis is to define the function of each chosen system.

4.9.2 Functional failure

A functional failure, occurs when the system is unable to fulfil its function, to an accept level of performance set by the user. This type of failure isn't only concerning the loss of a single function; it's also loss of partial failures that could influence the production or quality.

4.9.3 Failure mode

When all possible functional failures have been recognized, the analysis will proceed. The next step in the analyze process is to identify all kind of reasonable causes, that make a functional failure happen. This goes under the name failure mode. Under this step, all kinds of failure are represented, both those who have happened, but also failures that could or are likely to cause the functional failure. There are many types of failure modes, often from wear and fatigue.

4.9.4 Failure effects

Failure effects is the fourth step in the RCM process, and it describes what happens when each failure mode occur. This step is in close relationship with the next step and it should support the analyst to find out the following:

- in what way the failure is a threat to safety or the environment.
- in what way the production or operations are at risk.
- what physical damage is caused by the failure.

4.9.5 Failure consequences

In a Mill or maintenance organization, there can be over thousands of different failure modes. Each of these failures effect the organization/Mill in the same way, but in each case, the affect is different. They may affect personal safety, environment, product quality, production and operation capabilities.

A positive effect with the RCM method is that the user becomes aware of that the only reason for doing a proactive maintenance task is to reduce the failure consequence, instead of avoiding the occurrence of failures. [1] & [3]

The RCM processes have four categories of failure consequences:

- Hidden failure consequences
- Safety and environmental consequences
- Operational consequences
- Non-operational consequences

The RCM processes are using these four failure consequences to increase the safety in the organization. The failure consequence also helps the user to realize that there are several ways to managing failures. Failure managing techniques are divided into two categories:

- Proactive tasks
- Default action

More about the these failure managing techniques, can be studied in chapter 4.9.7

4.9.6 The RCM task selection process

After finishing step five in the RCM process, it's time for step six and the task selection. The RCM method uses a logic decision tree, in the form of a flow chart. For each step in the process, a logical question must be answered, yes or no. After ending the selection process, the RCM method will give some proposed maintenance tasks. After that, it's up to the analyst to compare the result from the RCM task selection process with today's maintenance, failure and operational history. From that analysis, some new solutions of proactive maintenance tasks will come out. The logic tree can be shown in enclosure 4 and 5. [1] & [3]

4.9.7 Default actions
This is the final step in the RCM process, if no proactive maintenance task has been found, a default action must be done. The RCM method has got three major categories of default actions, these are:

- Failure finding
- Redesign
- No scheduled maintenance

4.9.7.1 Failure finding
The failure finding tasks involve checking, whether something is still working. Failure finding applies only to hidden or not revealed failure systems.

4.9.7.2 Redesign
The redesign is what it sounds like, redesign of systems, reconstruction or modification. Redesign is done to the hardware that doesn't fulfill the requirements set by the Mill/organization. The redesign is expensive and is therefore used as a last resort, if the problems affect the operation performance in a negative way.

4.9.7.3 No scheduled maintenance
The no scheduled maintenance is most used when the failure is evident, and does not affect safety or the environment. The components are left in operation until they are either replaced or repaired, in other words they "run-to-failure".

4.10 The RCM audit process

After the RCM analysis is finished, an audit should be performed before implementing the new strategy into the organization. The senior management should order that an audit is performed, due to the fact that they are responsible if anything should go wrong. The audit should be performed by the senior management or someone that the senior management has assigned the audit too. The persons that perform the audit should be well trained of the RCM method.

The audit should be performed quite soon after the RCM process has finished. That's because people who conducted the analysis will see that their work, were not in vain.

The audit should review all the RCM documents both the RCM/FMEA analysis and the task selection with the logic decision diagram. Also should all written documentation be worked through, to see if any mistakes have been done [1] & [3].

At the audit, should also a discussion be held if any aid program be obtained. The best way of implement the aid programs are during the pilot project phase or as soon as possible. The aid program could be programs such as: condition monitoring, CMMS or an RCM database.

4.11 The RCM process

The RCM method has previously been described in detail and it's quite extensive. Therefore the image below can clear out some difficulties about the path the RCM analysis takes during it's analyze steps.

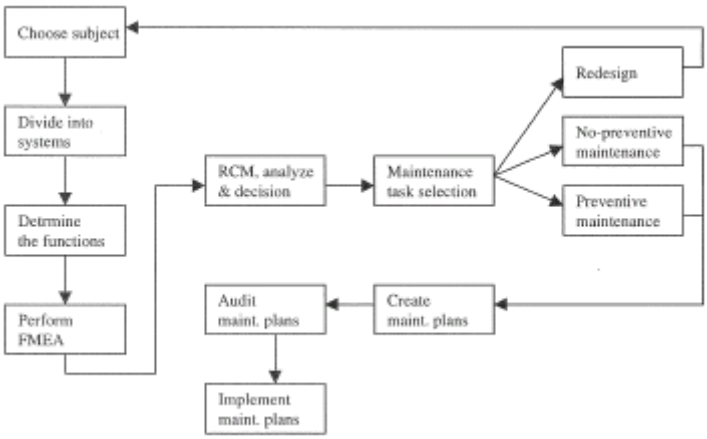


Figure 4 The RCM process

4.12 Outcome of the RCM method

The RCM method can give the following results: [1] & [3]

- Maintenance schedules
- Some suggestions of possible redesign items. The need for redesign is the final solution if an item cannot deliver it's desired performance.

The RCM method also brings some positive aspects, which are:

- Improved operational performance
- Lower maintenance costs
- Longer lifetime of expensive items
- Greater maintenance history
- Higher personal- and environmental safety
- Better teamwork and motivation of individuals

4.13 Modified RCM methods

There are several different modified RCM methods in the market today. The main difference between the classical way of RCM and the modified ones are that the modified RCM methods don't fulfill the SAE standard. These modified RCM methods goes under names such as PMO, Blitz RCM, and RCM 2. Nevertheless are these modified RCM methods any less better then the classical way, in some cases. That's because they have a different approach to the problem. Many of the modified RCM methods start with the already made maintenance plans and go from there and optimize them. Several of the modified RCM methods doesn't answer to all the seven questions or just some of them, according to the SAE standard

4.13.1 The PMO method

One of the most recognized modified RCM methods is the Preventive Maintenance Optimization. The PMO method is built on the same basis as the classic RCM approach. The difference between the two are, that the PMO method start with a complete maintenance schedules, instead of the classical RCM approach that starts in the design phase. The main difference between the two approaches can be found in the way of how failure modes are generated. The PMO method generates the failure modes from the selected organizations maintenance program and also analyzes the failure documentation even more then in the classical approach.

4.14 Maintenance methods

The maintenance of today can be divided into two major groups, preventive- and corrective maintenance. Preventive maintenance has also been divided into two categories, condition based- and predetermined maintenance. [5]

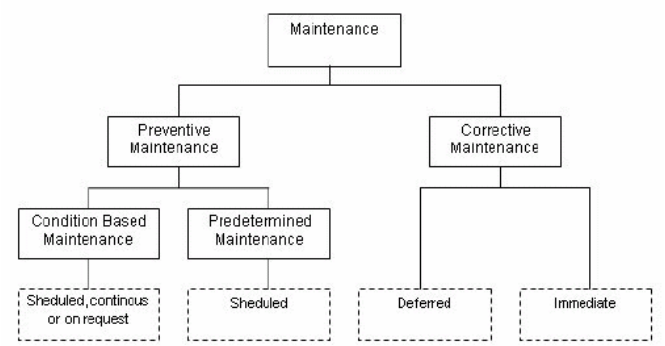


Figure 5 Different maintenance methods (SS-EN 13306, 2001) [19]

4.14.1 Corrective maintenance

Corrective maintenance is performed with the intention to restore a function after a failure has occurred. Corrective maintenance also goes under the name unplanned or unscheduled maintenance.

Corrective maintenance has been divided into two subgroups, immediate and deferred. Where the deferred maintenance has been chosen and is quite ok. The immediate maintenance is the negative one, which goes under the name unplanned.

4.14.2 Preventive maintenance

Preventive maintenance is a maintenance activity to reduce the probability of failure before the failure has occurred. This is done by either predetermined-, or condition based maintenance.

Predetermined maintenance is carried out according to maintenance schedules, in time intervals. Predetermined maintenance is done on the equipment regardless of the status of them. The intervals must be adapted, so that it don't become corrective maintenance. Predetermined maintenance is done on simple items or complex items with a high failure rate.

Condition-based maintenance is done through a maintenance schedule, but instead of exchanging the items directly, a check of the items status is done before replacing it. Condition-based equipment is also suitable for condition monitoring, due to the fact that all items give some kind of signals before they break.

5. The pilot project

In this chapter, the pilot project will be described

5.1 The Twin Wire Press

The twin wire press is a press system combining a number press rolls and two wires. The twin wire press is used in the mechanical pulping industry. Its overall function is to dewater/dehydrate the pulp that's coming from the raffiners in a slobbery consistence. [16-17]

Figure 6 The twin wire press

5.2 The background about TWP

The twin Wire press system have been developed during many years, due to the fact that the company has grown and more experience have been put in to the organization, during this time. The TWP machine have been refined numerous times to meet the standards of the time. Today's TWP machine is one of the best machines in the world and can produce large quantities of pulp [16-17].

5.3 The pulp flow into the TWP

Below the function process of the twin wire press system can shown. A more detailed presentation will follow on chapter 5.3.

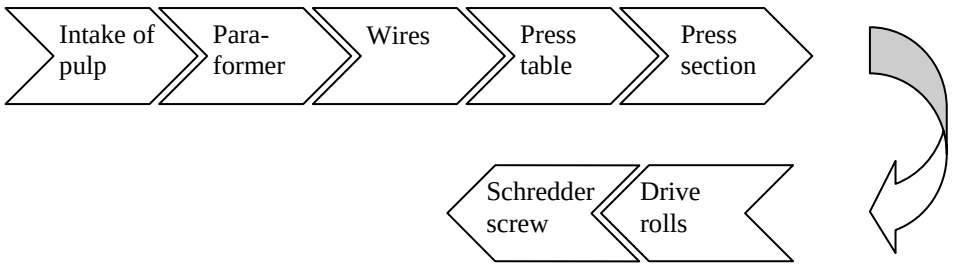


Figure 7 Pulp process through the TWP.

Here are the twin wire press sub-systems, these aren't in direct contact with the pulp which is going through the machine.

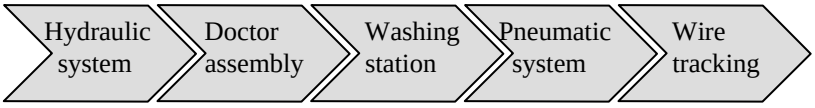


Figure 8 Sub process of the TWP.

5.4 The functions of the TWP-system

Under these headlines some basic information will be presented about how the processes are taking place of the TWP system. The flow process of pulp can be seen on the previous page [16-17].

5.4.1 The paraformer

The paraformer is the first sub-system on the twin wire press. The paraformer is constantly under pressure and provide the TWP with an evenly flow of slurry pulp. The paraformer are equipped with a transmitter system to monitor the pressure in the paraformer, so the machine can be shut down if a pressure peak should develop.

5.4.2 The wire

The next sub-system is the wires. The evenly distributed pulp slurry enters the TWP between two wires. These two wires move the slurry pulp, through the TWP machine.

5.4.3.The press table

At the same time as the pulp enters the wires, it also enters the press table. The press table consists of two parts, an over- and under section. The two sections of the press converge toward each other and thereby, forces water to extract from the pulp. The drained water from the pulp gathers first in storage tanks below the press and is later transported to the Mill's own recovering water system.

5.4.4 The press section

After the pulps have extracted some water, it enters the press section. In the press section there are a number of press rolls. These press rolls are working in pairs and the pressure increases after each pressure nip.

5.4.5 The drive rolls

When the pulps have passed through all the press rolls in the press section, there are only one final press nips, the drive rolls. The drive rolls are the key component in the twin wire press, due to the fact that they are driving the machine. The drive rolls are connected to a motor each, and they drive both of the two wires. There isn't any other propulsion then the drive rolls, of the TWP.

5.4.6 The shredder screw

The final procedure of the TWP is when the pulp moves to the shredder screw. The evenly pulp are distributed from the drive rolls and into the shredder screw. The shredder screw grinds the pulp into popcorn size and after this step the pulp moves to the next step in the pulp line.

5.4.7 The hydraulic system
The hydraulic systems of the TWP are divided into two parts, hydraulic components on the TWP and components beside the machine. The hydraulic unit beside the machine is the powering part of the hydraulic system. The hydraulic unit delivers hydraulic pressure to the machine by hydraulic pumps and motors. At the hydraulic unit there is also some cooling equipment for the hydraulic oil. The components on the machine are in general a hydraulic cylinder that delivers power to all the pressure rolls and to the wire tracking system.

1. Paraformer
2. Wires
3. Press table
4. Press section
5. Drive rolls
6. Shredder screw
7. Hudraulic unit
8. Doctor system
9. Shower system

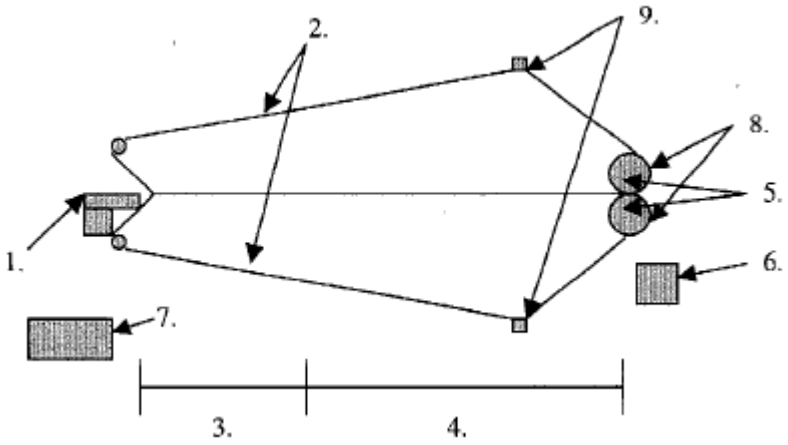


Figure 9 Twin Wire Press systems

5.5 Some sub-functions of the TWP

Under these headlines will information be presented that covers the basic functions of the TWP [16-17].

5.5.1 The doctor system
On each drive roll a doctor system is fitted. The doctor blade system is used to prevent pulp to get caught on both of the wires.

5.5.2 The shower system
The efficiency of a press largely depends on it's capability to drain water through each wire. Therefore it's crucial to keep both of the wires clean from fibers from the pulp and other contaminants. To achieve this TWP has got two showering system, each wire has got one showering system. The rinsed water from the showering system are collected and transported to the Mill's own recovering water system.

5.5.3 The wire tracking system
The wire tracking system keeps track of the wire during operations. The tracking devices can stop the TWP if there should be any unapproved events.

5.6 The TWP analyzed systems

The following systems have been selected for the RCM analysis: the paraformer, the press section, the drive rolls, the wires and the hydraulic system. These can be seen in figure 9.

6. Factory layout of a TMP Mill

The first step of making wood pulp is when a company harvest the trees in the forest. After the trees have arrived at the pulp mill, the will come to the wood handling station. At the wood handling station, the logs will first go through a de-ice chamber, then be washed and in the end, loose their bark in a debarking drum. That's because the bark only contains some usable fibers. Instead the bark will be used to create steam to the Mill. The debarked logs are then going to the chipping station, where they are being cut into small chips. After the chipping station, the chips go to the storage facility. The Mill is in constant use of chips, so therefore from the storage facility several screw feeder move the chips into the screening station. At the screening station all chips are being screened, so that to large chips and larger bits of logs can be chipped again before they can be used at production of pulp.

In today's pulp industry there are a lot of ways to go from here, making pulp. One of the more modern ways of making pulp is thermo-mechanical (TMP) way. After the chips have been screened, they are brought to the chip washing station. The chips are washed before refining, so that the lifetime will be maximized of the refiner segments. After the chips have been washed the chips are grinded with steam in the refiner. The grinded pulp is then pumped into an storage tower. Pulp that have been rejected, before pumped into the storage tower are being re-refined to pass the quality control. From the storage tower, the pulp can go in two different ways, it can either go to the paper line or it can be bleached. The pulp that's going to be bleached must first be post refined and then the pulp also must be dewatered in a twin wire press, before the bleaching procedure can be done. The pulp needs to be quite dry, to eliminate the use of high level of bleaching chemicals in the pulp. The bleaching chemicals are inserted into the system after the twin wire press and then the pulp goes to another storage tower. From the storage tower the pulp goes to some roll presses that dewater the pulp and make it dryer. Now the bleached pulp is ready to go to the paper Mill. In enclosure 6, a factory layout can be seen. [20-22]

7. Description of today's maintenance

In order to compare the suggestions from the RCM analysis, descriptions of today's maintenance process is needed.

The maintenance is in general performed by the factories/Mills own maintenance crew. The maintenance are performed from Metso Paper Inc., recommendations. Metso Paper is also offering a inspection agreement with the pulp-, and paper Mills to come and inspect their machines twice a year. Failures are mostly recognized during the indoor maintenance crew, but also by Metso crew performing inspections. The inspections are more extensive then the briefly checks performed by the indoor maintenance crew. [16-17]

The recommended maintenance of the selected sub-systems of the twin wire press are as follows:

Checks performed for every operator's shift:

- Wires:
  - Check that the wires are clean
  - Rotate the brushes to the showering system
- Press section:
  - Check for hydraulic leaks
  - Drive rolls:
  - Check for hydraulic leaks
- Hydraulic system:
  - Check for hydraulic leaks on the TWP
  - Check for hydraulic leaks on the hydraulic unit.

Checks performed weekly for:

- Drive rolls:
  - The drive unit is visual inspected
- Hydraulic system:
  - Check the level oil in the tank of the hydraulic unit

- Wires:
  - Check the wires for wear, especially near the edges.
  - Checks the wire extension.

Checks performed monthly:

- Drive rolls:
  - Measure the wear of the drive roll coating.

Checks performed during stop-sequence:

- Paraformer:
  - Inspect the paraformer visually

8. Different customer's operational conditions

Metso Paper in Sundsvall manufactures equipment for the pulp and paper industry, as mentioned before. Therefore they stand in a close relationship with their customer's, so that they can respond with technical expertise to any problems that should occur on their industrial lines. In most cases the relationship between Metso and the customer works without any problems at all, but in same rare cases the way of maintaining the plant can be a difficult question, due to other cultures regarding the operation and maintenance. It can also be some difficulties when a new method shall be introduced to a customer that are maintaining the facility on a complete opposite way of what is the orderly common way.

To introduce a new maintenance method into an organization requires some preparation to make it function well.

8.1 The RCM implementation process

When a company has decided to implement the RCM method into their organization, some steps must be taken to make the transformation as smooth as possible. The first step is to educate the company's management in the RCM method. This can be done in two ways: if there is competence about the RCM method in the company it can be conducted there, otherwise a consultant must be engaged in the learning process. The consultant will in this case represent the expert knowledge that requires conducting proper training to the management. When the management have received proper training and are committed to the RCM approach, then a core RCM team must be chosen which also must undergo proper RCM training. The management in close relationship with the core RCM team, will chose one or two pilot projects. The core RCM team will then work with the projects during a couple of months. At the same time, the management must conduct training to the departments of the company. When the pilot projects end, the management must evaluate the pilot projects performance and then present the result to the whole factory. After the result of the pilot projects have been evaluated then a complete implementation can be done to the whole organization.

Three different approaches to the implementation of the RCM Method
When planning to implement a new maintenance method, there are in general three different strategies to do so:

- the task force approach
- the selective approach
- the comprehensive approach

8.1.1 The task force approach

The task force approach can be implemented into organizations and companies that suffer from intractable problems that creates serious consequences. Then the companies form a task force that is going to work with the RCM method. The

company creates a small group that undergoes RCM training and then analysis the concerned systems. The group works full-time with the project, until they have reached a result and then the group split.

The main advantages with this kind of approach are that it's often quite quick and successful. There will also be a minor investment to the plant and the task force is easy to manage, due to small number of personal in the group. The main disadvantage of this approach are that it doesn't see long perspective and that the method will be forgotten in time.

8.1.2 The selective approach

The selective approach can be useful to organizations and companies that have problems that are difficult to identify. The characteristics of these failure and problems are often under the name: downtime, poor product quality and excessive maintenance cost. There can be thousands of items that are fulfilling this and that raises the question, which of these items should be analyzed by the RCM method. One way of selecting the items is to see if they are significant to the system. That meaning if they could breach any safety or environmental regulations or if they have significant economical consequences. If a item isn't classified as a significant item then it will not undergo a complete RCM analysis.

To easily see which of the significant items that are more important a probability tool is used. The tool is called probability and risk number – PRN. The tool consist of some probability scales that are used to generate a number, by multiplicating some appreciation of probability numbers with each other. A high number on the PRN scale could represent a sever problem. Those items that were classified with a high PRN number are first adapted to the RCM analysis. Those with lower PRN number are analyzed later.

The organizations and companies that are using this way of approach, is adopting between 20-40 % of their facility. The main advantage of this approach is that it's rather quick, due to the fact that only some parts of the facility undergoes analysis. It's also cost less then implement it on the whole Mill. The main disadvantage of this approach is that it concentrates on the technical system instead of the whole maintenance organization.

8.1.3 The comprehensive approach

The third and final approach handles the implementation of the RCM methodology into the whole facility. When implementing the whole facility, all personal must be motivated and committed to make it work. There will be teamwork over departments' boundaries in many RCM teams. The management can conduct a full implementation in two ways, through a implementation campaign or implement in stages.

If the management should choose to implement the RCM method in a campaign, then several RCM teams works side-by-side to cover the facilities systems. The teams are formed by employees and run by several group leaders. By doing this the whole

facility will be analyzed in a rather quick way. However by performing this large scale implementation a careful planning process must already have been done.
The other way of approach is to implement it, step by step. By doing so, there will be less involvement of the facility personal. Instead of having several RCM teams working side-by-side, by performing this approach you just need 4-5 teams that are working parallel, under one or two leaders. On this basis, it could take three to five years to implement the whole facility.

The main advantage of this approach is that it will secure the company in the long perspective. It also generates better teamwork between the departments. The main disadvantage of this approach is that it is much slower, due to the fact that many more people must know how the RCM method works. Therefore this approach is more difficult to handle, due to all the people involved. [1], [6]

8.2 Different cultures

When companies are expanding into new parts of the world, some cultural problems may occur. These problems may occur on several different levels, and so it can be many different solutions to it. Therefore to have a industry success in an other part of the world, it's very important to study and know the different culture. A definition of what a culture is, could be as follows:[9]

> *"a set of basic assumptions – shared solutions to the universal problems of external adaptation (how to survive) and internal integration (how to stay together) – which have evolved over time and are handed down from one culture to another"*
> (Schein, 1985)

What the definition represents is that how a company shares the different solutions with other companies abroad, regarding markets and customers. At the same time shares unique solutions to expand.

There can be several levels of culture in an organization. When dealing with a company, it can be good to know how to indicate these levels of culture and from them act. The most visible level of culture is the culture artifact level. In this level national settings are exemplified by traditional modes of greetings, dress codes, forms of address and title each other. For example, titles are used quite different around the world, in Germany titles are very common but in the USA titles aren't so common in relationship with Germany. Another level of culture is the espoused values, which refer to the goals and norms of behavior in a particular country. In this level, also the national beliefs will play a particular roll, for example Swedes values job security among other things and German value product quality. At the deepest level of culture are the basic underlying assumptions, these are the most difficult values to change. Why they are so difficult to change is because they represent the taken-for-granted beliefs and also consists of the thoughts and feelings that shape values. All these three culture levels can be seen below [9]

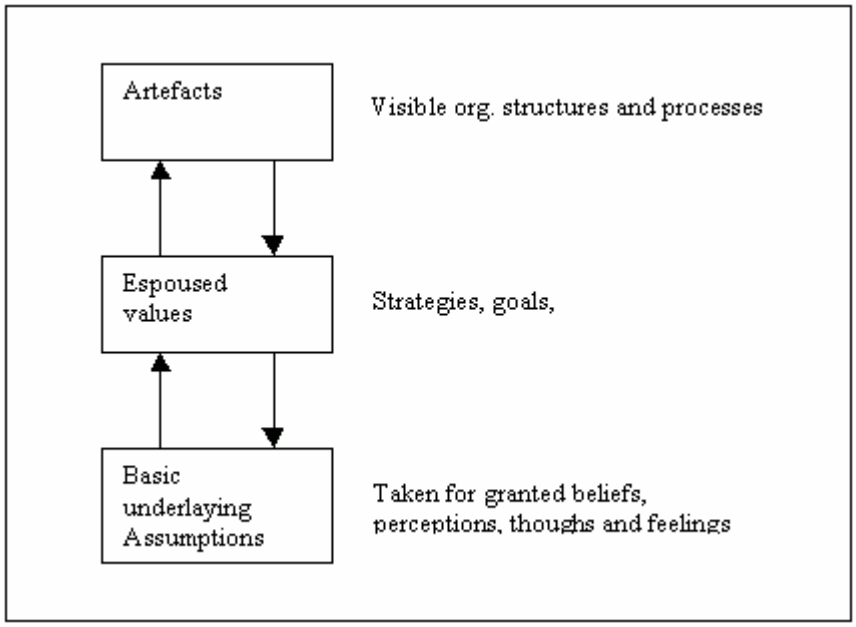


Figure 10 Different culture levels [9]

When taken the above culture levels in consideration, regarding maintenance condition abroad. This could create a new aspect of why the maintenance procedures may be a little different. Also in today's level of technology many of the world's maintenance procedures are quite the same. In the modern technology society you aren't able to generalize about the standard of maintenance. Therefore, the standard of each company must be treated one-by-one.

8.3 Planned change

Before a new maintenance method can be adopted a great deal of planning must be done. The planning should be done by the top management of the company. They have to decide the general guidelines for the RCM implementation as a whole and also plan the RCM project. The general guideline states what will be carried out of the RCM process, such as: which approach should be used, decide goals and objectives, estimate how many RCM meeting will be needed, also how much time and personal that should be used. The top management should also plan what the RCM team should do, who will participate and every details around the team.

It's important that those who plan the change are highly linked with the employees of the organization during the planning phase. If they aren't, the employees of the organization are less likely to follow the regulations of the plans [10]

To successfully implement a new maintenance method into an organization, it requires a plan. One of these implementing plans could be seen in enclosure 7 [9].

8.4 Organizational learning

When implementing a new maintenance method in other operational condition, it's not the method that should be changed; it's how you implement it. Therefore organizational learning and change of management that's important. Organizational learning concerns many things, the general path is that organizational learning is linked with individual learning and that the individual learning acquire skill and experience to the organization. One other aspect of organizational learning is about what takes place in an organization before, under and after an implementation of a new method [11].

The knowledge of an organization comes at the beginning from its employee's. It starts with individual employee's that learns through a mental model. A mental model is a idea of how a problem can be solved. Every individual have several thousand's different mental model, each for each kind of problem. There aren't any rights or wrongs in the mental models only if they are helpful or not.

Organizational learning starts when individuals start to share the mental models with each other. The knowledge then becomes rooted in the groups/departments of a organization. When the organization starts to learn is when the group/departments are implementing the knowledge into their actions and routines. That's because the organization shouldn't be independent of any individuals. The process of sharing mental models and learn over boundaries aren't easy. It isn't only the willingness of sharing information; the hard part is to accept other who sharing different kind of information that must be accepted of the general population. To make an organization more willing to learn, motivation of its employee's is really important.

One good example of how strong shared metal models are, could be as follows: "Consider two cases. In the first all data and documents belonging to an organization would disappear overnight. In the second, all employees in an organization are replaced by outsiders." It would be easier to start up with all the employees, due to the fact that all mental model are still left in the company. It's the shared mental models that makes the other part of an organizations memory, the primary are all the printed documents. The picture below show how the organization learns from its employees. [11]

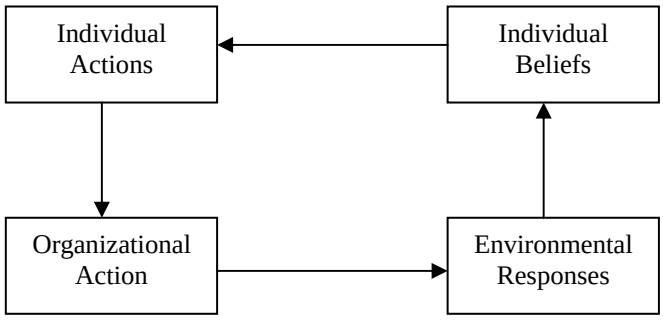


Figure 11 Learning processes of organizations

8.5 Communication

One of the most important issues in an organization is to have a functional ways of communication. The right communication will bring both understanding and commitment when a new method should be implemented in the organization. A common mistake by the top management is to under communicate with its employees, regarding new principals. This could lead to that the message the management wanted to get out, losses the dignity. It's also important that really

Sometimes the change of new methods tends to stall, and one of the reasons to that could be communication. If there have been similarly projects previously that have gone wrong, these experiences will tend to follow the employee into the next project of similarly type. Often the lack of information about the result of projects, have lead to lack of motivated people. [12]

8.6 Condition monitoring

Condition monitoring is a technique to monitor the condition of equipment. In today's maintenance industry are there several hundred different condition monitoring techniques. They are all working in the same way, to detect potential failure effects, such as vibrations, changes in temperature, particles in lubrication oil, leaks and so on. The condition monitoring solutions are a extension of the human senses, such as smell, noise, and heat. Due to the fact that a transmitter – computer based system manage to supervise a system better over a long period of time, and also are cheaper then humans.

The condition monitoring techniques are data based solutions, which have several transmitter devices installed in the machine or on the system. Then the information from the transmitters is send to a computer for analysis. The computer can also be hooked up to a CMMS system that provides several organizations with operational information about the system. The information from the condition monitoring equipment results often in updated curves with different alarm levels. So if, a level would be broken, an alarm would warn the operator about the on-going process. [1]

Metso Paper has developed a condition monitoring equipment, by the name FalconView™. For the moment this equipment are installed in to different kinds of refiners, around the world. The system provides the operator, with an early warning system if anything starts to go the wrong way. The operator can also get support from Metso personal regarding maintenance questions.

A suggestion is to convert the FalconView™ to the TWP system. This would give Metso Paper more information about the TWP system in operation conditions and also provide their customers with all the benefits that belongs to it. [18]

8.7 CMMS

A CMMS is a software program that's designed to assist the management with planning, manage different kind of administrative functions to make the maintenance process as good as possible. The system helps the management to store and trace operational and failure history. It also records everything that concerns the maintenance and maintenance plans. The CMMS can also be fitted with financial tool which provide an economical approach to basic approach. A basic CMMS often includes the following sub-parts:

- Equipment data management
- Preventive maintenance
- Labor
- Work order system
- Planning
- Vendor
- Inventory control
- Purchasing
- Budgeting

There are under preventive maintenance (PM) the RCM method will earn from the usage of the CMMS system. Every task in the RCM process that has been classified with PM, can the CMMS program call up a work order. The CMMS keep track of the work order details, labor, parts and tools. The program also helps the maintenance management with the priority of work order. When it's time for a specific work, the CMMS generate a work order. The CMMS also keep track of the amount of spare parts that the Mill have in stock. The condition monitoring tool, which have been described previously, is also included in a CMMS. The CMMS can therefore reduce time consumption, in an organization. [13]

8.7 Agreements

Metso Paper is making maintenance agreements with their customers. These agreements include almost everything, from how to maintain different machines to what happens when system breaks. It can be difficult to formulate these agreements, so they cover everything. A suggestion would be if Metso Paper could obtain more operational performance-, and failure data. This would both the Metso Paper and their customers gain on. The data could help update their current maintenance plans, but also help Metso Paper to improve the machines.

9. Data collection and analysis

A complete pilot study was performed to the five selected sub-systems of the Twin Wire press. The sub-systems that were analyzed were the following: paraformer, press section, drive rolls, wire and the hydraulic system.

The first step of the RCM method is to choose what are to be analyzed. After consultation with the company's supervisor, the Twin Wire press system was selected. The Twin wire press system was developed from earlier models of the same principle. After the choosing the component for my analysis, the component were broken down into various sub-systems. The selection of the five sub-systems mentioned above, were chosen due to high failure frequency and were causing decreased production rate.

Before the RCM/FMEA analysis could take part a RCM/FMEA spreadsheet was created, also some education material was made. The RCM/FMEA analysis part was conducted in interview form, instead of gathering the whole group. The interview's were conducted during several meetings with Metso staff, and this were done due to high workload of Metso staff.

After completing the RCM/FMEA analysis part, a comparison was made with today's maintenance. Then the RCM decision part was conducted with the RCM decision tree.

After the decision part was done, some new maintenance tasks were proposed.

10. Discussion

The RCM/FMEA analysis resulted in some suggestions of change to today's maintenance. These suggestions have been chosen from the RCM process of the five selected sub-systems, that have gone through a complete RCM analysis. Due to Metso policy, the result from the RCM/FMEA analysis will not be presented in this thesis report. Instead an example of how the RCM/FMEA analysis process have been carried out, will follow.

- A *Sub-system* have been chosen for RCM/FMEA analysis.
- The *Function* is to measure the pressure in a unit.
- The *Functional Failure* is that, the unit displays the wrong pressure.
- The *Failure Mode* are caused by, that the unit could be: wrong calibrated, mounted in a wrong way, and/or suffer from a broken cable
- The *Failure Effect* could increase pressure to the unit and/or lead to stop of production.

The RCM analysis must fulfil seven basic questions according to the SAE standard, to be a true RCM method. Above, four of the seven questions have got answers, to complete the RCM method three more questions needs to be answered to. The last three questions/steps will not be shown in this example, due to company policy.

The next step, step five, the RCM analysis process defines whether the functional failures are: hidden/evident, have a safety or environmental consequences, have a operational consequences or not.

Step six handles the RCM task selection process. This step decides what kind of proactive maintenance task the selected system/component should have. The last step, is to define what should be done if no proactive maintenance task is suitable for the system/component.

11. The achievement of this thesis

This thesis report will gain the following for Metso Paper:

- Performed a RCM/FMEA analysis of the TWP system
- Defined the RCM method
- Come with suggestions of how to implement the RCM method in other customer's conditions

12. Conclusions and recommendation for further work

According to the objective, the main reason for this thesis, to find a number of solutions to different questions regarding the RCM process.

What's needed to perform a RCM analysis?

The RCM method must have the support from the management, due to the fact that they are approving the resources needed to perform the method in a right way. Therefore it is important to give the management education of what the RCM method stands for and what the outcome are. When the RCM method have a good support from the management, then the RCM method can start, and have the possibility to success.

A RCM team should be created, and the composition of analyze personal should consist of peoples from different working areas. That's because then all possible of approaches will be described. The case for Metso Paper, is to get operational, and failure history from the customers Mill. After the groups have been gathered an education must take place. That's to set a basic level of knowledge for the group, so they can handle the RCM analyze and perform it well.

The RCM process are quite resources demanding, in all kind of approaches. The primary resource that's needed to use RCM is time. During the RCM process, a guiding value could be to have RCM meetings a couple of times each week. The whole RCM analysis on a specific system should be done on 5-15 meetings.

Before the RCM method can be implemented into operational conditions, the result of it must go through an audit process.

What's really important is that after the RCM method have been deployed in operational conditions, a revision must be done. This is done to keep the RCM method and all its documents in an updated way. If no revision is taking place, the method will decrease in effectiveness. When new systems have gone through the RCM analysis, then you'll see which statements from the RCM analysis, are true.
Therefore it's really important to revise these documents, as mentioned previously.

Which are difficulties with the RCM method?

There can be some difficulties when to decide what level the analysis should be performed on. If the RCM teams are not consisting of a mixture of people, especially personal from the operational side, it can be hard to know what's happened in a day-to-day basis with the selected system. There can also be some problems regarding the RCM process, which failures that should be categorized in which compartment.

What are the suggestions of how to implement the RCM method?
When implement the RCM method in other customer operational conditions, the first thing that must be done, is to recognize what type of cultures the companies have. Today's maintenance industries are far more developed than a couple of years ago. Therefore, the differences between continents aren't so big. You're not able to generalize the maintenance standard between continents, instead look at the difference between companies. Therefore it's really important to recognize the maintenance culture in each company

The education that the companies get must be adapted to each company or rather to its pattern. It's important to educate and also motivate the employee's of the company, due to the fact that they are living the implemented maintenance program. If the employee's don't have the motivation, the program will fail or work inefficient.

The RCM method could be implemented in three ways, in this aspect a fully implementation would be to prefer. How much implementation should be done, is a question for the CEO and top management.

To keep track of all the information from the RCM method, some kind of CMMS would be good to use.

A vital part of the RCM analysis is to get information from all stages of the maintenance process. Therefore would it be good to convert the existing condition monitoring program FalconView™, to also monitor several other systems that Metso Paper provides.

When arranging the agreements with customers, it would be good to have an exchange of information regarding operational-, and failure history. Having this information many steps of the RCM process would go much easier in the future. This favors both Metso Paper and it's customers.

Recommendations for further work
Metso Paper in Sundsvall has got many years of experiences in some parts of the RCM process. It would therefore be good, to start up one or two large scale pilot project and involve more people in them. At the same time involve more personal into the RCM concept, so the organization would have a plain level of knowledge about the RCM method in the concerned departments.

It would also be good to document every failure, even the little ones. This would increase the failure knowledge and make the RCM analysis easier.

When adapting the RCM method abroad, some more research about the country should be done to prevent any mistakes during the educational process. Due to the fact that in many countries in Asia always replies yes or no, when direct question are asked. In this case more opened questions must be used.

In the agreements part, it would be good to formulate an exchange of information, from their customers.

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Metso Paper information

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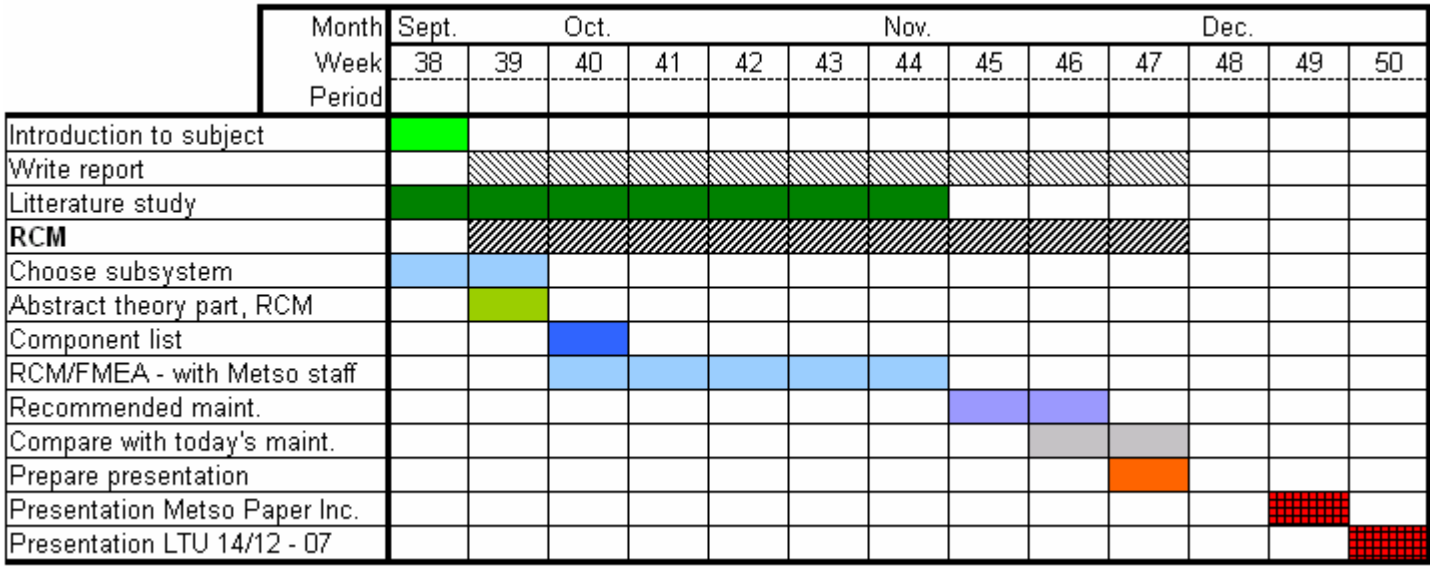
ENCLOSURE 1


Month
Sept.
Oct.
Nov.
Dec.
Week
38
39
40
41
42
43
44
45
46
47
48
49
50
Period
Introduction to subject
Write report
Litterature study
RCM
Choose subsystem
Abstract theory part, RCM
Component list
RCM/FMEA - with Metso staff
Recommended maint.
Compare with today's maint.
Prepare presentation
Presentation Metso Paper Inc.
Presentation LTU 14/12 - 07

ENCLOSURE 2

FAILURE MODE AND EFFECT ANALYSIS (FMEA) FOR MOST COMMON FAILURES

Mill: **Target:** **Date:** **Compiler:**
Drawing: **Specialist:**
Segment: **Position:**

No.	Component	Function	Characteristics of failure			Control	Detection	Occ.	Sev.	Det.	RPN	Remark
			Functional failure	Failure mode	Failure effect							
1												

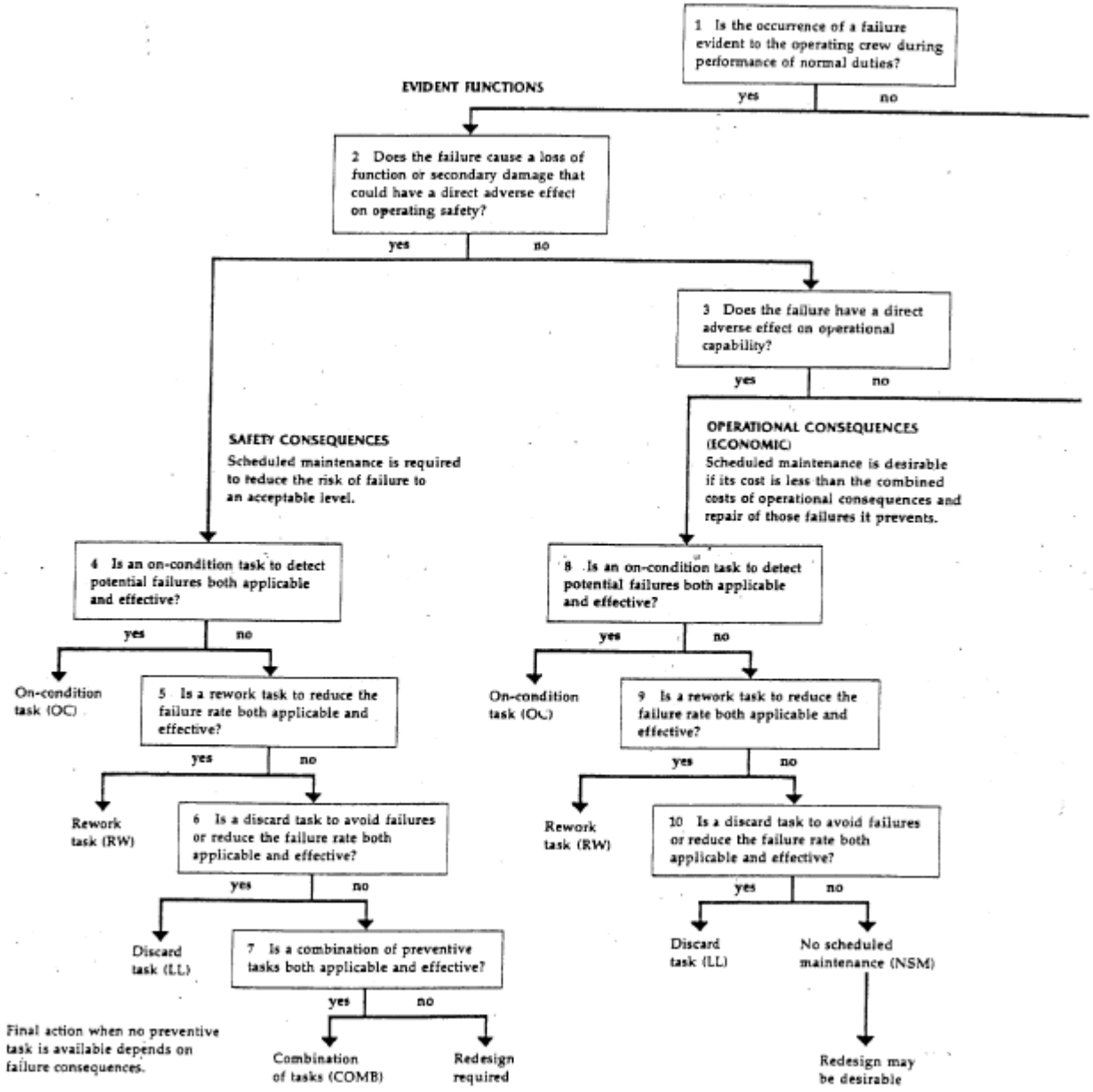
ENCLOSURE 3

Item name:

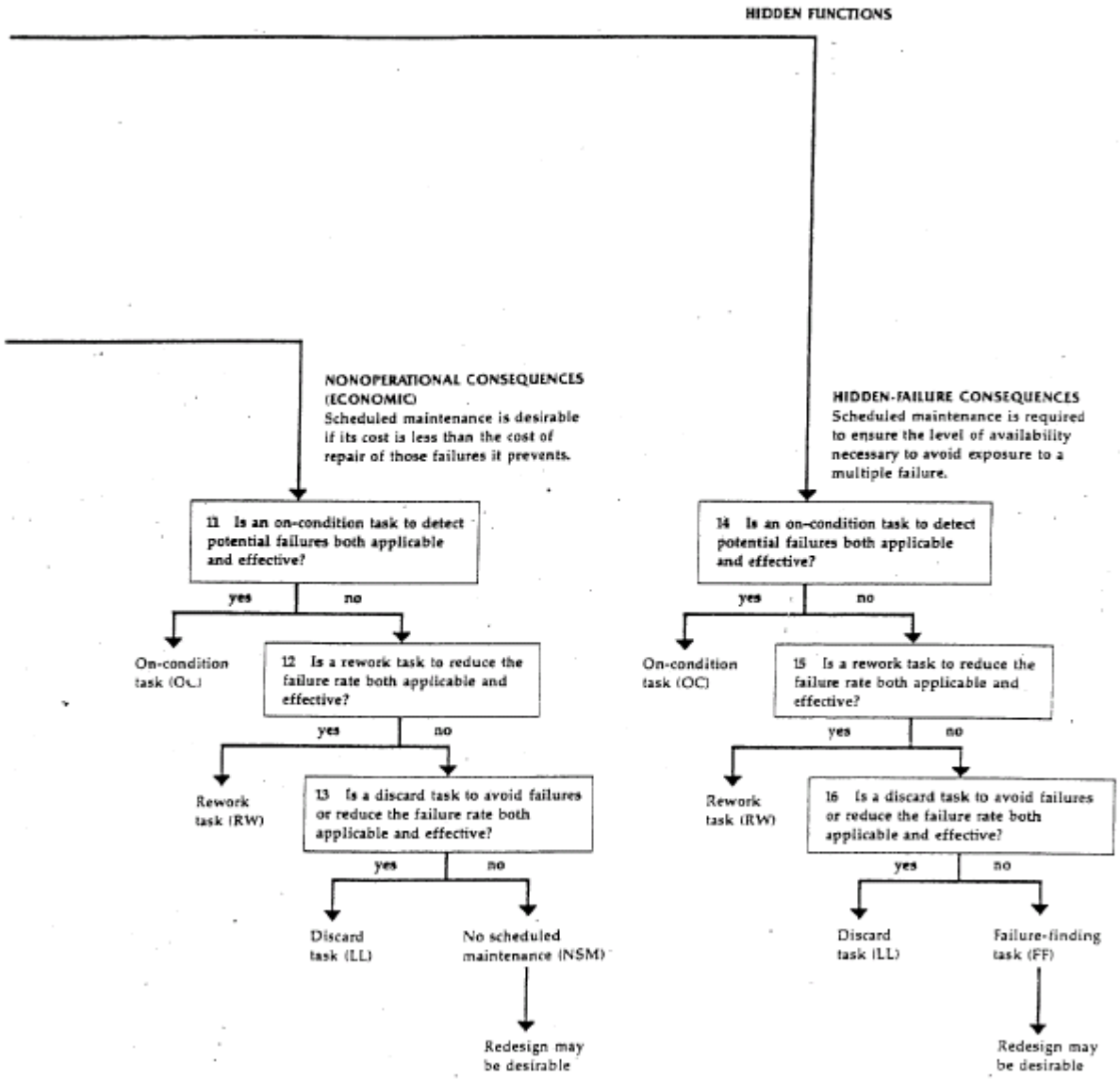
Responses to decision diagram questions

Ref.				Consequences				Task selection												Proposed task:	Initial interval:
No.	F	FF	FM	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		

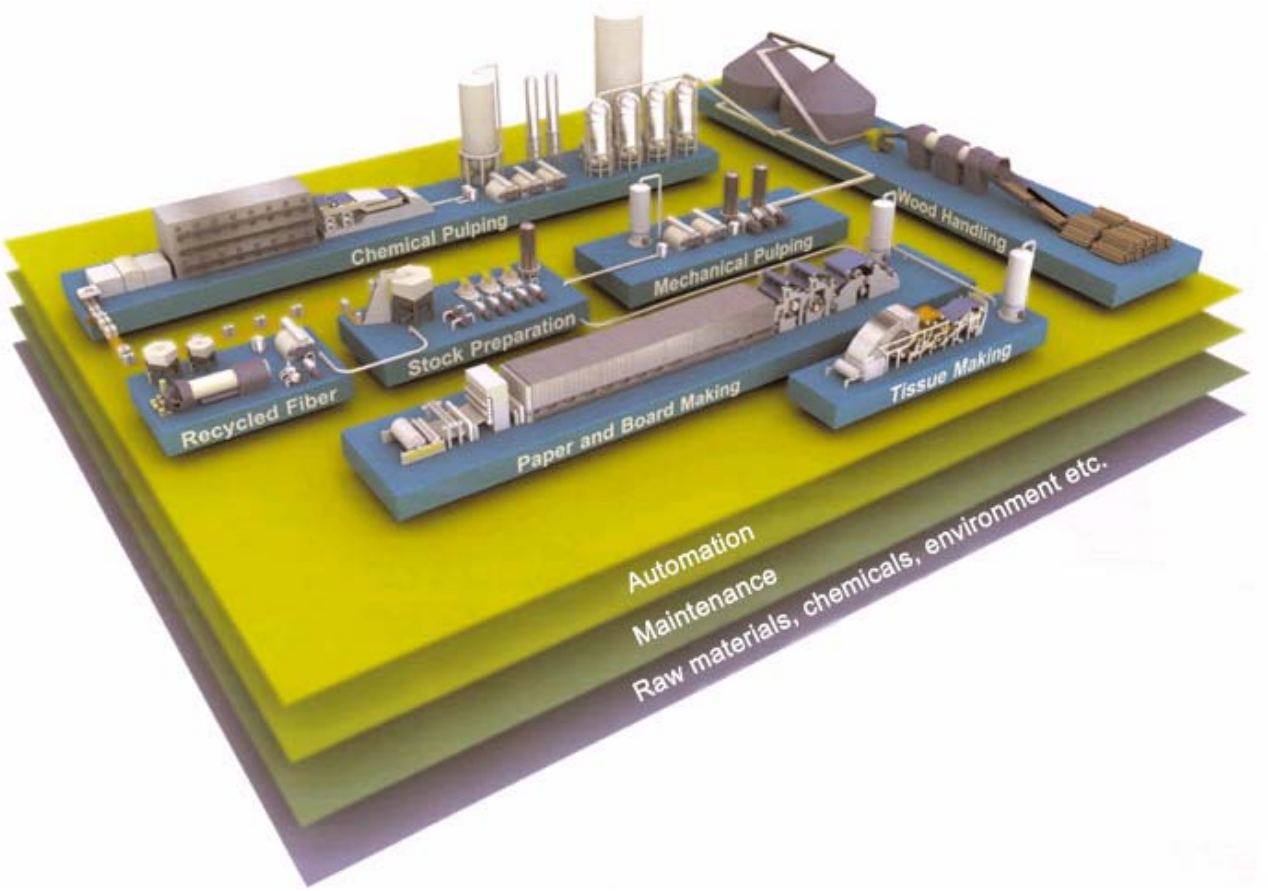
ENCLOSURE 4


1 Is the occurrence of a failure evident to the operating crew during performance of normal duties?
yes
no
EVIDENT FUNCTIONS
2 Does the failure cause a loss of function or secondary damage that could have a direct adverse effect on operating safety?
yes
no
3 Does the failure have a direct adverse effect on operational capability?
yes
no
SAFETY CONSEQUENCES
Scheduled maintenance is required to reduce the risk of failure to an acceptable level.
OPERATIONAL CONSEQUENCES (ECONOMIC)
Scheduled maintenance is desirable if its cost is less than the combined costs of operational consequences and repair of those failures it prevents.
4 Is an on-condition task to detect potential failures both applicable and effective?
yes
no
On-condition task (OC)
5 Is a rework task to reduce the failure rate both applicable and effective?
yes
no
Rework task (RW)
6 Is a discard task to avoid failures or reduce the failure rate both applicable and effective?
yes
no
Discard task (LL)
7 Is a combination of preventive tasks both applicable and effective?
yes
no
Combination of tasks (COMB)
Redesign required
Final action when no preventive task is available depends on failure consequences.
8 Is an on-condition task to detect potential failures both applicable and effective?
yes
no
On-condition task (OC)
9 Is a rework task to reduce the failure rate both applicable and effective?
yes
no
Rework task (RW)
10 Is a discard task to avoid failures or reduce the failure rate both applicable and effective?
yes
no
Discard task (LL)
No scheduled maintenance (NSM)
Redesign may be desirable

ENCLOSURE 5


HIDDEN FUNCTIONS
NONOPERATIONAL CONSEQUENCES (ECONOMIC)
Scheduled maintenance is desirable if its cost is less than the cost of repair of those failures it prevents.
HIDDEN-FAILURE CONSEQUENCES
Scheduled maintenance is required to ensure the level of availability necessary to avoid exposure to a multiple failure.
11 Is an on-condition task to detect potential failures both applicable and effective?
yes
no
On-condition task (OC)
12 Is a rework task to reduce the failure rate both applicable and effective?
yes
no
Rework task (RW)
13 Is a discard task to avoid failures or reduce the failure rate both applicable and effective?
yes
no
Discard task (LL)
No scheduled maintenance (NSM)
Redesign may be desirable
14 Is an on-condition task to detect potential failures both applicable and effective?
yes
no
On-condition task (OC)
15 Is a rework task to reduce the failure rate both applicable and effective?
yes
no
Rework task (RW)
16 Is a discard task to avoid failures or reduce the failure rate both applicable and effective?
yes
no
Discard task (LL)
Failure-finding task (FF)
Redesign may be desirable

ENCLOSURE 6


Chemical Pulping
Mechanical Pulping
Wood Handling
Stock Preparation
Recycled Fiber
Paper and Board Making
Tissue Making
Automation
Maintenance
Raw materials, chemicals, environment etc.

ENCLOSURE 7

Factors for successful organizational change

1. Know where you starting from. Usually, a receptive context for culture change togheter with the managerial ability to create a positive climate for culture change is necessary. One useful maxim that seems to apply is that often big change produces big opposition in the threatening the social identites of key players and their investment in the status quo.

2. Estabilsh a sense of urgency by creating the necessary levels of tension (or mechanisms of discomfort) in the organization for cultural change, and by assembling and facillitating a powerful group of people who act as champions to lead the change.

3. Create a vsion (though it may, and perhaps should, be imprecise) and/or values framework which should hellp direct the culture change effoert.

4. Use all possible means to communicate the vision/values deep into the organization (see the use discourse and strategy as convincing stories) and ensure that managers ’walk the walk’ to demonstrate the importance of the new culture and the kinds of behaviours associated with it.

5. Empower others to act by removing structural blockages to the new culture (e.g. organizational and architectural), and encourage innovation and group activites.

6. Encourage and use ’deviants’ and heretics to critically evalute existing practice by ’speaking up the power’ and bring in fresh ideas.

7. Plan for and create short-term wins to encourage long-term persistence with the culture change initiatives.

8. Reinforce changes in culture with changes in structure and in the reward systems to reflect the kind of behaviour that are appropiate.

9. Be aware of ethical issues, personal chices and questions that most people have to face when being asked to commit themselves to culture change. These include: what can people reasonably be expected to do in the name of the organization, what kind of vision and values are people likley to buy into (how do they define the key stakeholders), how closely should the organization touch on peoples private lives and what values do they place on different kind of justice ?

10. Finally, be patient and persistent, as major changes in culture and structure may take many years to bring about.