Machine Reliability and Condition Monitoring

A Comprehensive Guide to Predictive Maintenance Planning

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No AI-generated text, translation or images were used in the production of this work.

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INTRODUCTION TO RELIABILITY AND RELIABILITY CENTERED MAINTENANCE RCM

The RCM philosophy employs Preventive Maintenance (PM), Predictive Testing and Inspection, Repair (also called reactive maintenance) and Proactive Maintenance techniques in an integrated manner to increase the probability that a machine or component will function in the required manner over its design life cycle with a minimum of maintenance. The goal of the philosophy is to provide the stated function of the facility, with the required reliability and availability at the lowest cost. RCM requires that maintenance decisions be based on maintenance requirements supported by sound technical and economic justification.

As with any philosophy, there are many paths, or processes, that lead to a final goal. This is especially true for RCM where the consequences of failure can vary dramatically. Rigorous RCM analysis has been used extensively by the aircraft, space, defense, and nuclear industries where functional failures have the potential to result in large losses of life, national security implications, and/or extreme environmental impact.

A rigorous RCM analysis is based on a detailed Failure Modes and Effects Analysis (FMEA) and includes probabilities of failure and system reliability calculations. The analysis is used to determine appropriate maintenance tasks to address each of the identified failure modes and their consequence. For more information about FMEA, read the book A Practical Guide to FMEA.

Equipment/Maintenance Reliability Definition

The instantaneous likelihoods of failure for a specific piece of equipment during a specific time period.

RCM Analysis

The RCM analysis carefully considers the following questions:

• What does the system or equipment do; what is its function?

• What functional failures are likely to occur?

• What are the likely consequences of these functional failures?

• What can be done to reduce the probability of the failure, identify the onset of failure, or reduce the consequences of the failure.

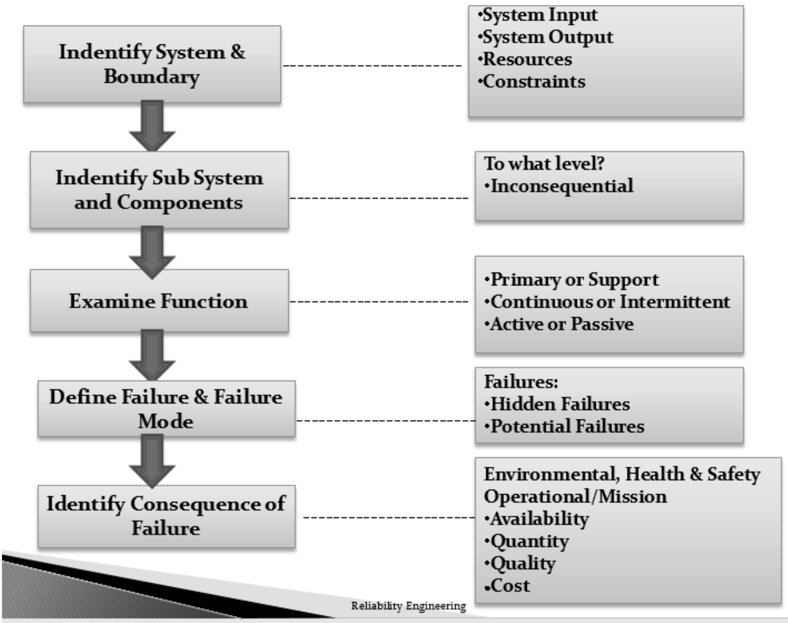
RCM Goals

- ✓ To ensure realization of the inherent safety and reliability levels of the equipment.

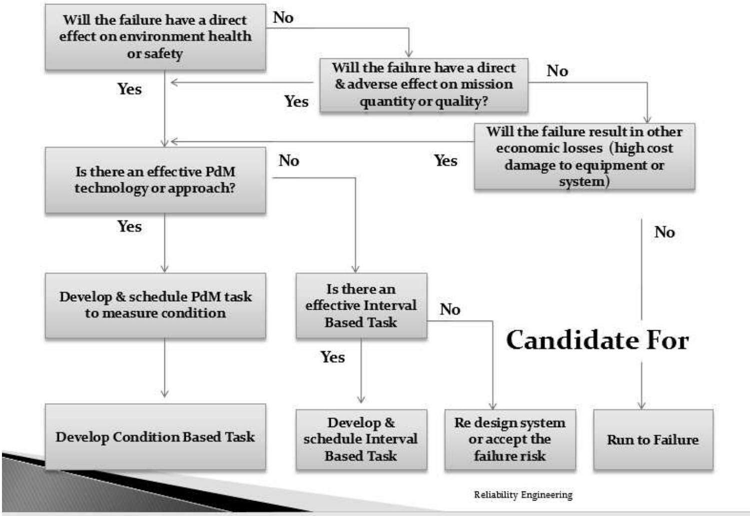
- ✓ To restore the equipment to these inherent levels when deterioration occurs.
- ✓ To obtain the information necessary for design improvement of those items where their inherent reliability proves to be inadequate.
- ✓ To accomplish these goals at a minimum total cost, including maintenance costs, support costs, and economic consequences of operational failures.

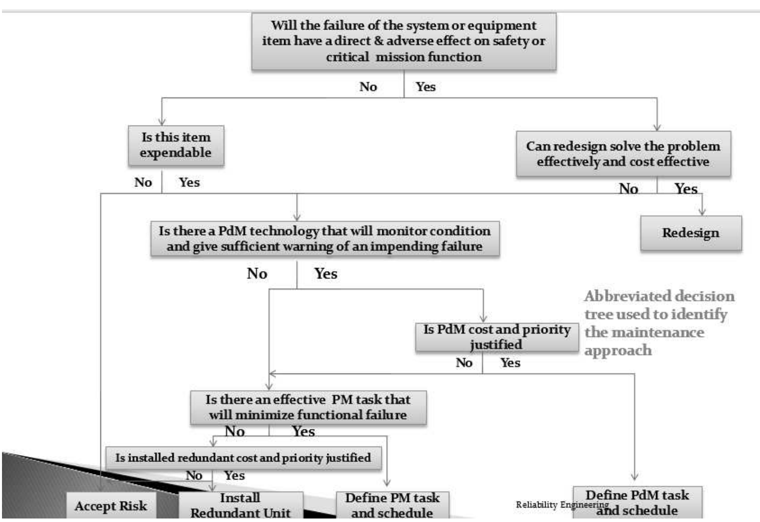
Reliability centered maintenance (RCM) is a reliability tool that is used to ensure the inherent designed reliability of a process or piece of equipment through the understanding and discovery of equipment functions, functional failures, failure modes and failure effects. In performing a RCM analysis, the RCM team uses a structured decision process to develop mitigating tasks for each failure mode identified

RELIABILTIY ANALYSIS

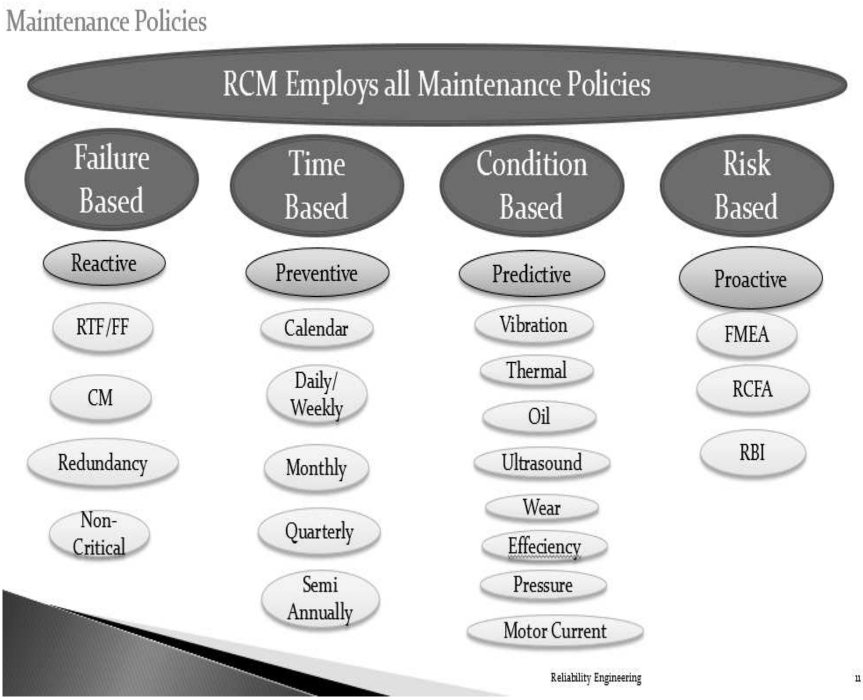


Maintenance Analysis





MAINTENANCE POLICIES AND STRATEGIES

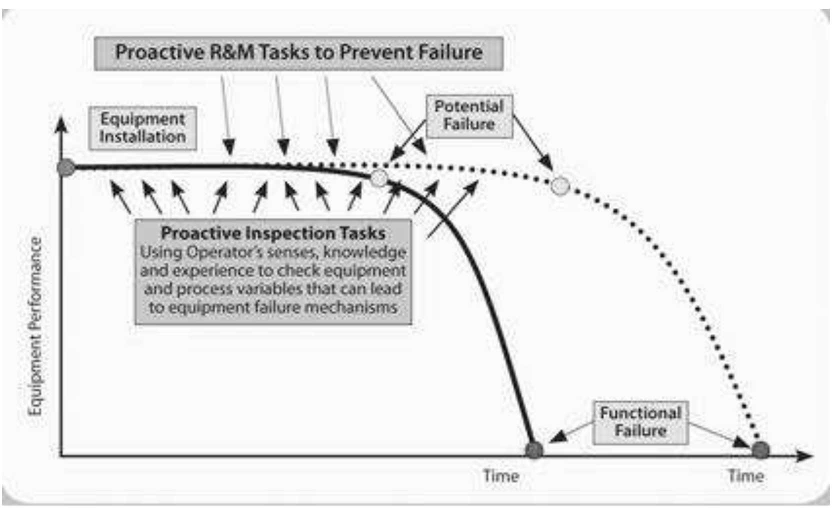


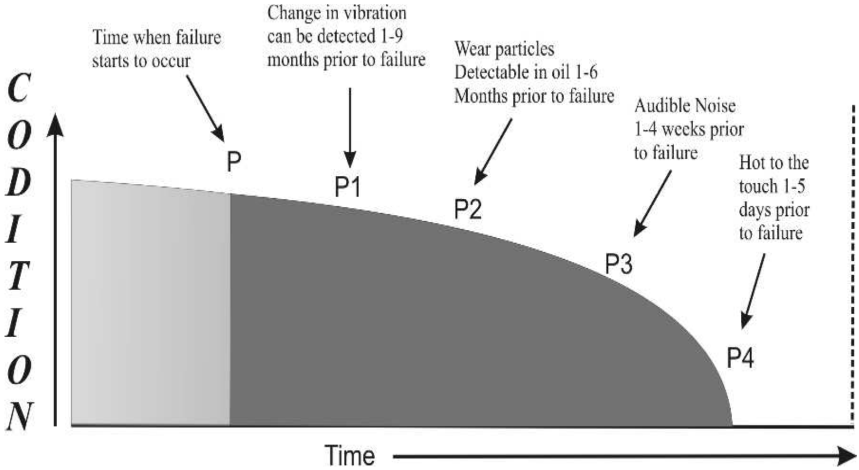
RCM promotes the use of Predictive and Risk Maintenance policies for identified critical equipment

PREDICTIVE MAINTENANCE TECHNIQUES

Predictive Maintenance Embraced by Plant Maintenance

Technique	Application	Pumps	Electric Motors	Diesel Generators		Condensers	Heavy Equipment/ Crane	Circuit Breakers	Valves	Heat Exchangers	Electrical Systems	Transformers	Tank Piping
VIB Analysis		•	•	•			•						
Oil Analysis		•	•	•			•					•	
Wear Analysis		•	•	•			•						
IR Analysis		•	•	•	•	•	•	•	•	•	•	•	
Ultrasound		•	•	•	•			•	•	•	•	•	
Non-Destructive testing (Thickness)					•				•			•	
Visual Inspection		•	•	•	•	•	•	•	•	•	•	•	•
Motor Current Analysis			•										





Time when failure starts to occur
Change in vibration can be detected 1-9 months prior to failure
Wear particles Detectable in oil 1-6 Months prior to failure
Audible Noise 1-4 weeks prior to failure
Hot to the touch 1-5 days prior to failure
P
P1
P2
P3
P4
CONDITION
Time

RELIABILITY KPIS

KPI	Description
MTBF	Mean Time Between Failure
No of failures addressed by root cause analysis	>75%
Ratio of PM work orders to CM work orders generated by PdM inspection	
OEE (Overall Equipment Effectiveness)	Availability x Reliability x Quality (85%)
Percent of Faults Found in Predictive maintenance Survey (Vib, IR, UT, OA)	No of faults found/ No of devices checked (target <3%
Percent of equipment covered by condition monitoring	Target= 100%
Reliability of critical equipment	99%
Facility Availability	>98%
Availability of critical equipment	>98%
Percent emergency maintenance	<5%
Percent planned maintenance	90%

EQUIPMENT CRITICALITY ANALYSIS

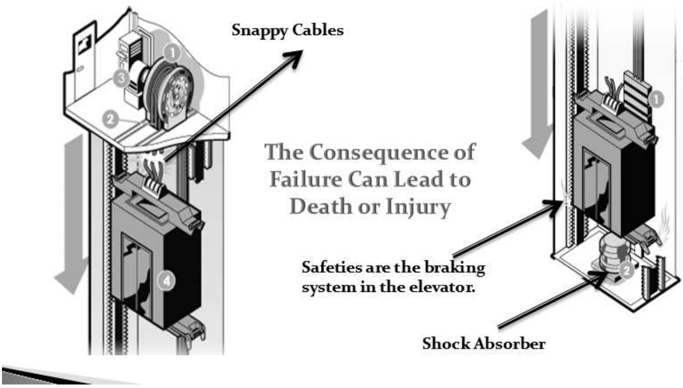
Importance of Equipment Criticality Analysis involves:

1. Influence the priority assignment of the Work Orders.
2. Influence the Work Orders execution speed.
3. Determine which Maintenance Class should come first.
4. Effect the scheduling of the preventive maintenance program.
5. Influence the priority of the preventive maintenance work.
6. Help in determining which maintenance approach to be used.

Criticality Measuring Principles

1. **Safety**

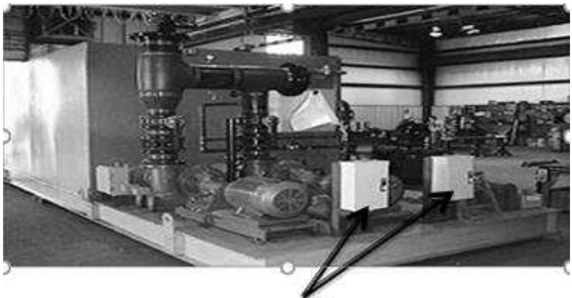
- ✓ Safety equipment (equipment carrying peoples, firefighting system, and alike).
- ✓ Consequence of parts failure effect safety (elevator ropes broken, firefighting generator stopped…etc).
- ✓ Gas piping leakage at any point poses a risk.



2. Production, Process

- ✓ Equipment breakdown affect the whole production line.
- ✓ Equipment breakdown affect partially the production line.
- ✓ Equipment failure has native effect on production quality.

The Consequence of Failure Can Lead to Process Shutdown, Major Losses, or Quality Problem.



Criticality decreases with redundancy in the system.

Criticality is influenced by the availability of standby equipment in a system but how much time does it take for the standby equipment to operate? And what is the effect of this on the production?

3. **Time (Time=Money)**

1 min production=How much?

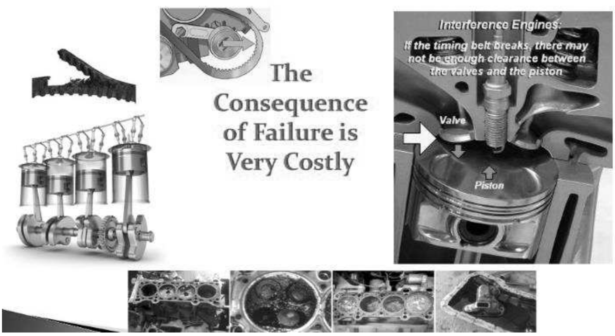
1 Hr production =How much?

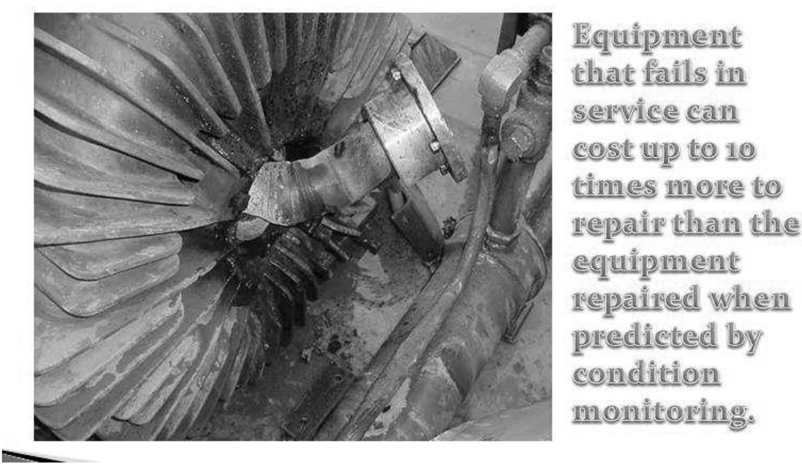
If your equipment is classified as critical, ask yourself the following questions:

- What is the preventive maintenance program I have for it? Enough? Or not?
- How much time does it take to repair it in case of failure?
- Spare parts allocation? Available? Not available? If not available, how much does it take to allocated it from the vendor?

➢ Require special skills for repair? Is my team trained to repair it in a proper time?
➢ Do you have an emergency plan for it in case of accident or failure? Is your team aware of this plan and trained on it?

4. Money, Cost





VIBRATION ANALYSIS

INTRODUCTION AND TERMINOLOGIES

Vibration can be defined as simply the cyclic or oscillating motion of a machine or machine component from its position of rest.

Displacement:

It is the amplitude of a point on a structure.

Velocity:

Is the speed of a point in a system, it is the rate of change of displacement.

Acceleration:

Is the rate of change of velocity of a point in a system.

Frequency:

Is the no of cycles (vibrations) per second, measured by hertz (HZ)

Harmonics:

Frequency component at a frequency that is an integer (whole number e.g., 2X. 3X. 4X, etc.) multiple of the fundamental (reference) frequency.

How many RPMs in 1 hertz?

Since hertz is in sec, and RPM is in minute, 1 hz= 60 RPM.

How to convert RPM to Hertz?

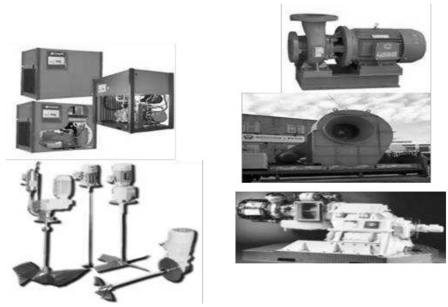
1500RPM = 25hz

Why we measure the vibration?

- ✓ To detect what is out of the human sense.
- ✓ To discover hidden failures.
- ✓ To Detect early failures & monitor the machine health condition.
- ✓ To assure the quality of repairs.
- ✓ As a useful tool to improve the maintenance Reliability.

Common Industrial Applications:

- Pumps
- Fans
- Turbines
- Agitators
- Stirrers
- Compressors
- Electric Motors
- Gearboxes



Vibration& Reliability

Vibration analysis alone doesn’t improve reliability, root cause analysis and acceptance testing can help.

There are two ways that we can utilize vibration to improve reliability:

First, if we study the vibration, we can often determine why the fault condition developed in the first place; for example, what caused the crack to appear in the inner race of the bearing? If we perform root cause failure analysis, we can make chances to our proactive so that the bearing doesn’t suffer the same fate in the future.

Second, when we overhaul the machine, we can again use the vibration analysis to check that the maintenance repair has been made correctly; and that the machine is correctly aligned and balanced, this called acceptance testing.

Vibration is still used to monitor the health of the machine, but if we improved the reliability of the machine, we will see fewer faults’ conditions develop.

Measuring With Smart Sensors “Collecting Data”

Analysis with Smart Software