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## Pillar 3 - Equipment Reliability

3.3 Establish a strategic plan to assure reliability of existing equipment



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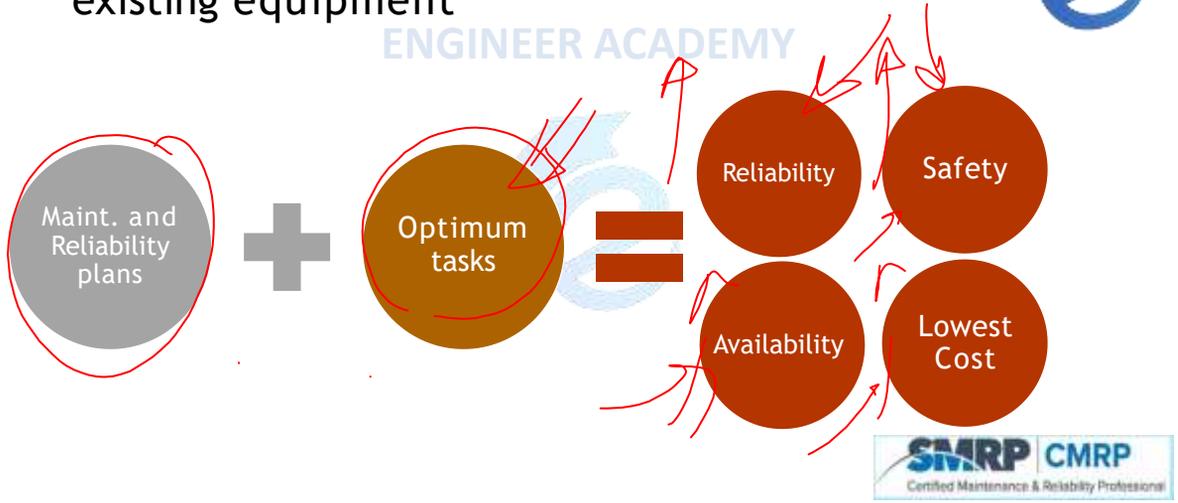
Identify appropriate analysis techniques

Develop maintenance strategy and tactics



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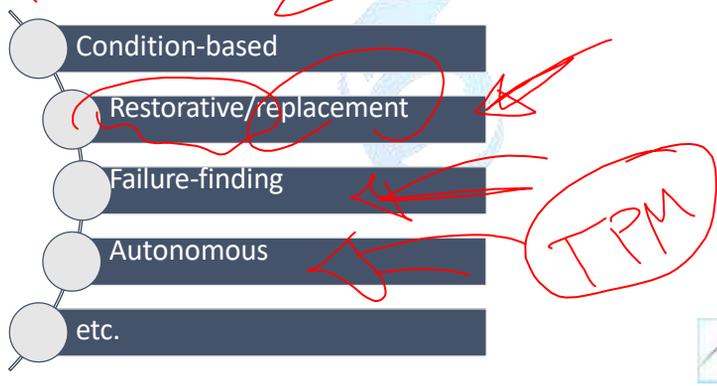


## Pillar 3 - Equipment Reliability

3.3 Establish a strategic plan to assure reliability of existing equipment



Maintenance activity types :



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Maintenance activity types:

- Time Directed (TD) tasks, (Calendar/run time based PMs)
  - scheduled restoration tasks
  - scheduled discard tasks
- Condition Directed (CD) tasks, (CBM/PdM tasks) (scheduled on-condition tasks).
- Failure Finding (FF) tasks (operator supported tasks)
- Run-to-Failure (RTF) tasks (economical decision based)



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- For condition-based tasks to be applicable:
  - it must be able to detect the potential failure condition
  - And there must be a reasonable, consistent amount of time between the first indication of potential failure and the actual failure.
- For time based overhaul tasks:
  - There must be an identifiable age at which the component fails.
  - And it must be possible to restore the original failure resistance through rebuilding or overhaul
- For failure finding tasks:
  - The equipment must be subject to a failure mechanism that is not evident to personnel during normal operation.

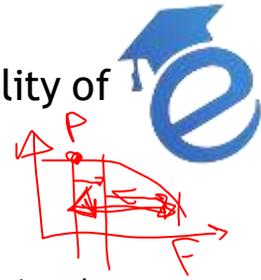


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Task frequency can be summarized in the following questions:

1. How frequently does the failure mechanism that the task is aimed to address occur?
2. How much time elapses between equipment failure initiation and functional failure?
3. Is there an adequate mechanism to measure the failure progression or component degradation?



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CFR

monitoring

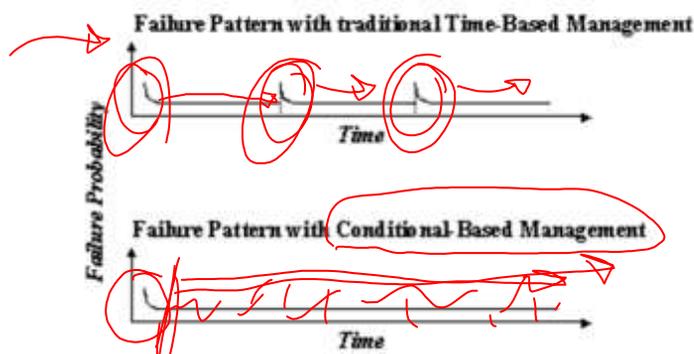


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Defining Task Interval:

#### Failure Patterns



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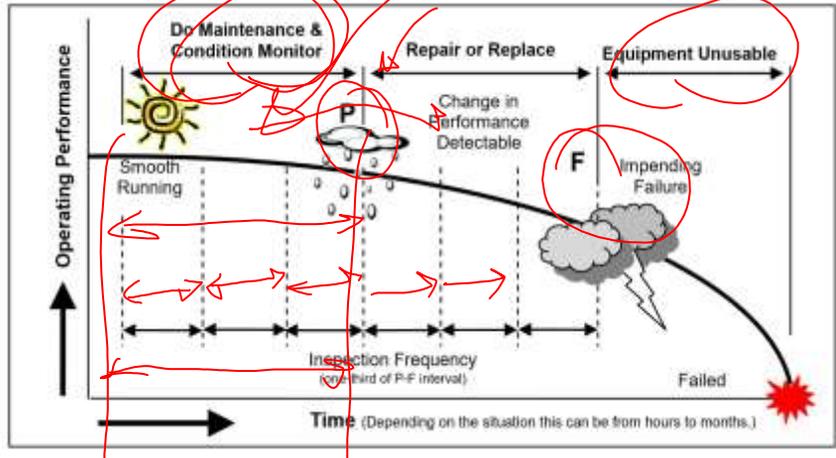
### 3.3 Establish a strategic plan to assure reliability of existing equipment



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Defining Task Interval:

Condition Based Tasks:



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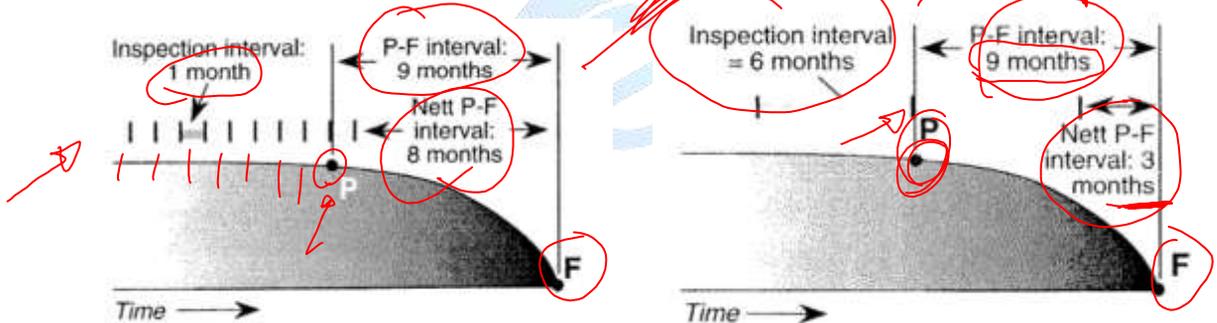
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Defining Task Interval:

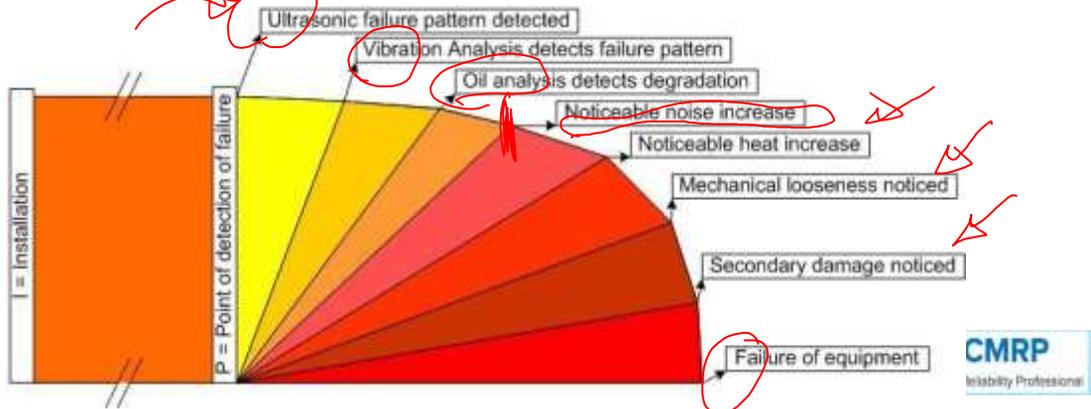
Condition Based Tasks:



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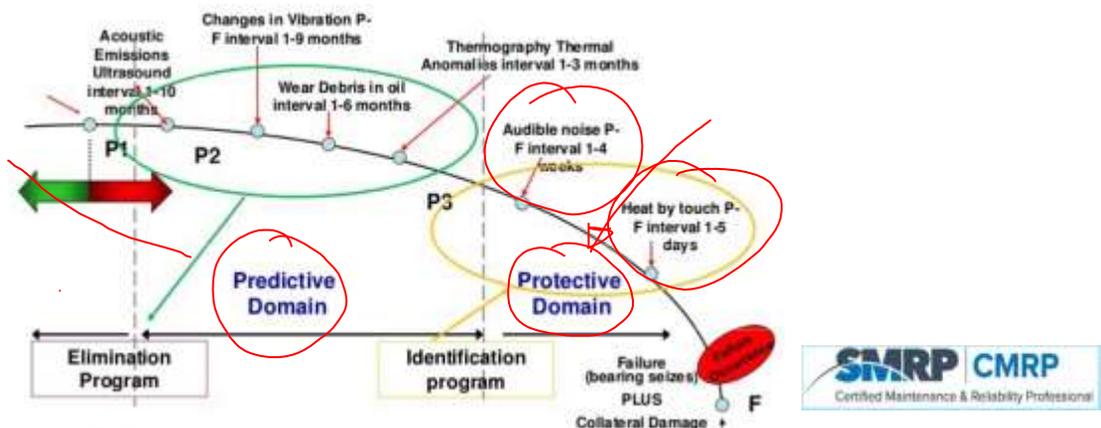
Maintenance Activity Types: Condition Based Maintenance



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

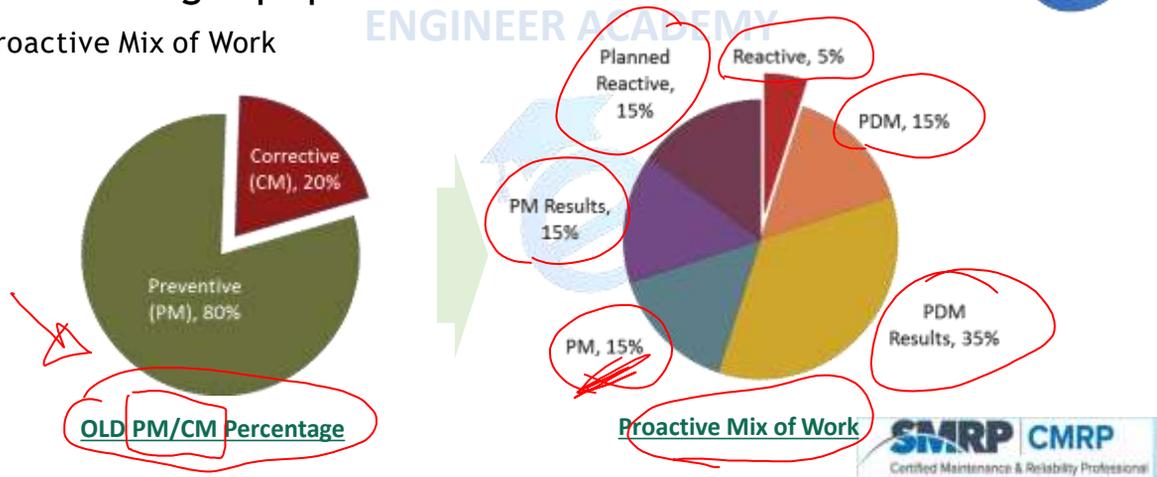
Maintenance Activity Types: Condition Based Maintenance



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Proactive Mix of Work



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Condition Based Maintenance: Vibration Analysis

#### Vibration Analysis

Vibration analysis is the dominant technique used for predictive maintenance management. Since the greatest population of typical plant equipment is mechanical, this technique has the widest application and benefits in a total plant program.



This technique uses the noise or vibration created by mechanical equipment and in some cases by plant systems to determine their actual condition.



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Condition Based Maintenance: Vibration Analysis

Magnitude of Vibration is Expressed As

- **Displacement** - The total distance traveled by the vibrating part from one extreme limit of travel to the other extreme limit of travel. This distance is also called the "peak-to-peak displacement."
- **Velocity** - A measurement of the speed at which a machine or machine component is moving as it undergoes oscillating motion.
- **Acceleration** - The rate of change of velocity. Recognizing that vibrational forces are cyclic, both the magnitude of displacement and velocity change from a neutral or minimum value to some maximum. Acceleration is a value representing the maximum rate that velocity (speed of the displacement) is increasing.



Figure 6.5.3. Typical vibration transducers.

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Condition Based Maintenance: Vibration Analysis

Magnitude of Vibration is Expressed As

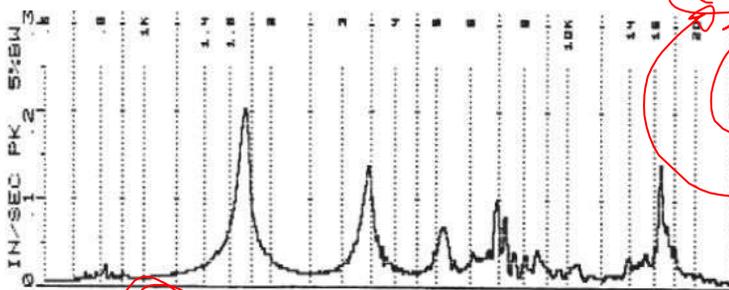


Figure 6.5.2. FFT - Example of graph breaking down vibration level at different frequencies



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Condition Based Maintenance: Vibration Analysis

Magnitude of Vibration is Expressed As

<b>Amplitude</b>	An indication of the <b>severity</b>
<ul style="list-style-type: none"> <li>Amplitude is important, but <i>change in amplitude</i> is more important</li> </ul>	
<b>Motion</b>	An indication of the <b>structural</b> response
<ul style="list-style-type: none"> <li>Use phase to learn more about the fault and check for resonance</li> </ul>	
<b>Frequency</b>	An indication of the <b>nature</b> of the fault
<ul style="list-style-type: none"> <li>Many tools are available to interpret the pattern</li> </ul>	

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Condition Based Maintenance: Vibration Analysis



Examples of typical hand-held vibration sensing meters. Note readout providing immediate level indication.



Typical Vibration Analyzer - Note liquid crystal display providing actual vibration waveform information in addition to machine condition analytical capabilities.



Some signal acquisition and analysis equipment interface a PC directly with the sensors.

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#### Condition Based Maintenance: Vibration Analysis

A selection of common detectable failure modes are:

*Imbalance:* a peak at shaft speed. (1X)

*Misalignment:* typically 1x, 2x & 3x shaft speed

*Looseness:* often at 1x or 2x shaft speed

*Bearing Damage:* higher frequency peaks typically between 2 KHz and 5 KHz depending on shaft speed and transducer resonance.



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AMT ← Gear  
 Jmp ← Components

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#### Condition Based Maintenance: Vibration Analysis

*Electrical Problems:* synchronous frequency and side bands.

*Gear Damage:* gear mesh frequency depending on shaft speed and number of teeth and side bands.  $GMF = N \times RPM$

*Oil Whirl:* approximately half shaft speed.

*Blade Damage:* number of blades by shaft speed.

*Cracked Shaft:* typically 2x, 3x shaft speed.



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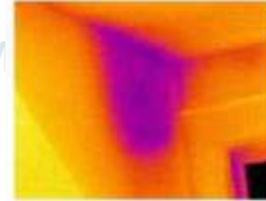
BPF  
 VPF

(N X RPM)

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Condition Based Maintenance: Thermography



Temperature measurement (Thermograph) is a useful indicator of electrical or mechanical condition such as the load applied to a thrust bearing. As a bearing fails, friction causes its temperature to rise. The use of infrared cameras or installing thermocouple sensors in the housing of a bearing and measuring temperature changes within the bearing or lubricant allows problems to be recognised early (potential failure).



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

Condition Based Maintenance: Thermography



- Allows the condition monitoring technician to determine if fault conditions exist in mechanical, electrical and plant process applications.



Figure B.2.1. Typical IR spot thermometer.

Handwritten red scribbles and the text "OK 935" are present over the bottom right portion of the slide.



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

Condition Based Maintenance: Thermography



- Infrared thermography allows the technician to determine if an object is hotter than it was (or hotter than it should be).
- Temperature readings can be taken two ways: spot radiometer or thermal imaging camera.

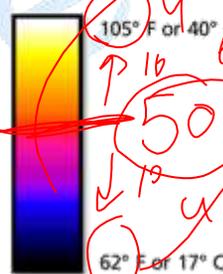


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Condition Based Maintenance: Thermography

- Thermography provides an entire color coded image: the temperature scale is set so that the cooler temperatures are black/dark blue, and the hotter temperatures are yellow/white.



~~SPAN RANGE~~



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Condition Based Maintenance: Thermography

Example Applications

- Steam Systems
  - Boilers
    - Refractory
    - Tubes
  - Traps
  - Valves
  - Lines
- Heaters and furnaces
  - Refractory inspections
  - Tube restrictions
- Fluids
  - Vessel levels
  - Pipeline blockages
- Environmental
  - Water discharge patterns
  - Air discharge patterns
- Motors and rotating equipment
  - Bearings
    - Mechanical failure
    - Improper lubrication
  - Coupling and alignment problems
  - Electrical connections on motors
  - Air cooling of motors



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Condition Based Maintenance: Thermography

Example Applications



Figure 6.2.6. Warm inboard motor bearing. Image taken in a manner to readily compare IR images of several running motors.



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Condition Based Maintenance: Thermography

Example Applications

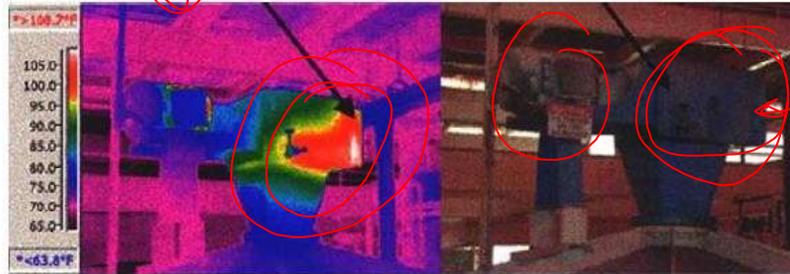
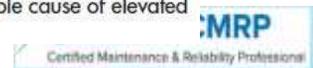


Figure 6.2.7. Possible gearbox problem indicated by white area defined by arrow. Design drawings of gearbox should be examined to define possible cause of elevated temperatures.



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Condition Based Maintenance: Thermography

- Temperature will increase when there are "shorts", high resistance joints, or excessive current flow. Applications include:

Example Applications

Components*	Components
3 phase power distribution	Fuse boxes
Cables and connectors	Relays and switches
Insulators	Capacitors
Substations	Circuit breakers
Controllers	Transformers
Motors	Battery banks



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Condition Based Maintenance: Thermography



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- These components are monitored in order to detect the following fault conditions.

Example Applications

Fault conditions*	Fault conditions
Unbalanced loads	Harmonics
Underspecified components (e.g. fuses)	Loose or corroded connections with increased resistance in the circuit
Insulation failure	Overloaded systems/excessive current
Wiring mistakes	Component failure

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Condition Based Maintenance: Thermography



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Example Applications

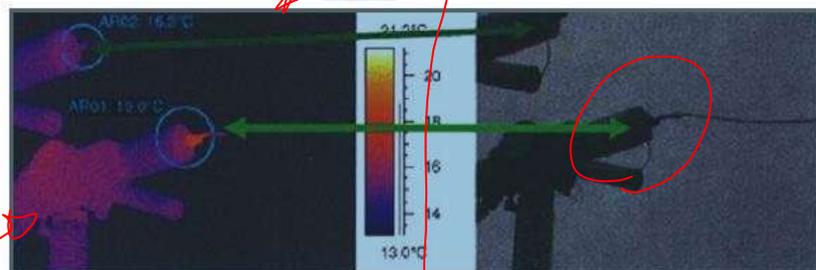


Figure 6.2.4. Air breaker problem. Note temperature difference between these air breaker contacts seen inside green circles.

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Condition Based Maintenance: Thermography



Example Applications

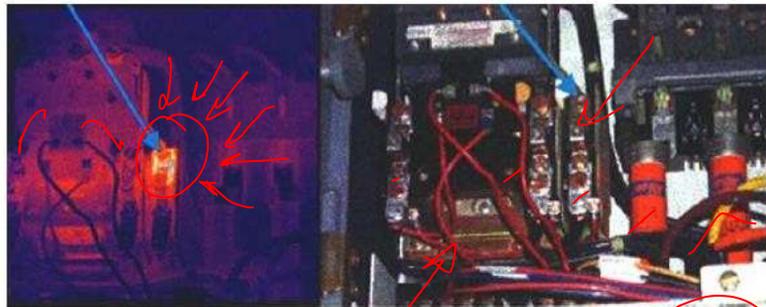


Figure 6.2.5. Overload connection problem. Note difference in IR image coloration between overload contacts.

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Condition Based Maintenance: Ultrasonic Inspection

Anal: 20K → 200KHz

Very high frequency, acoustically transmitted vibration is measured with a high frequency piezoelectric sensor. This sensor is excited by compression waves produced by metal-to-metal contact and by metal as it mechanically fails. The acoustic flow detection signal is conditioned to produce outputs which can be measured as numerical values on a meter. These measurements are used to judge the overall condition of a bearing and evaluate local defects. This technique is highly effective in very early detection of bearing failure.

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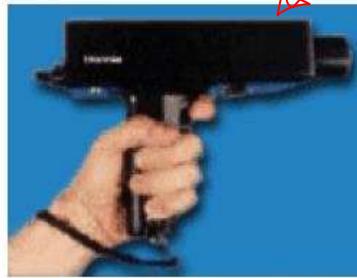
## Pillar 3 - Equipment Reliability

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Condition Based Maintenance: Ultrasonic Inspection



Parabolic dish used with ultrasonic detector greatly extends detection range abilities.



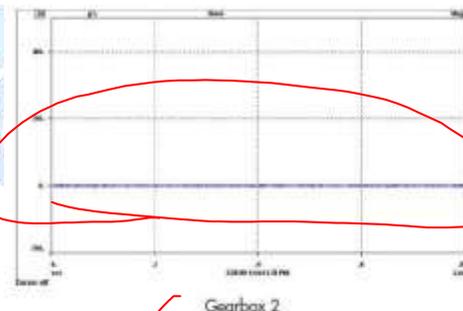
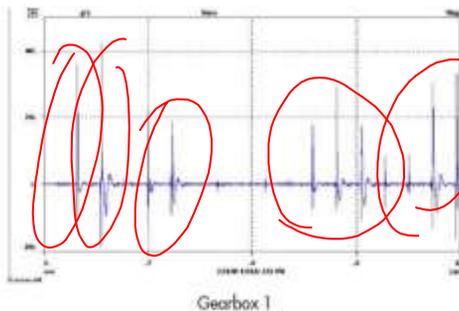
Typical hand-held ultrasonic detector.

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Condition Based Maintenance: Ultrasonic Inspection

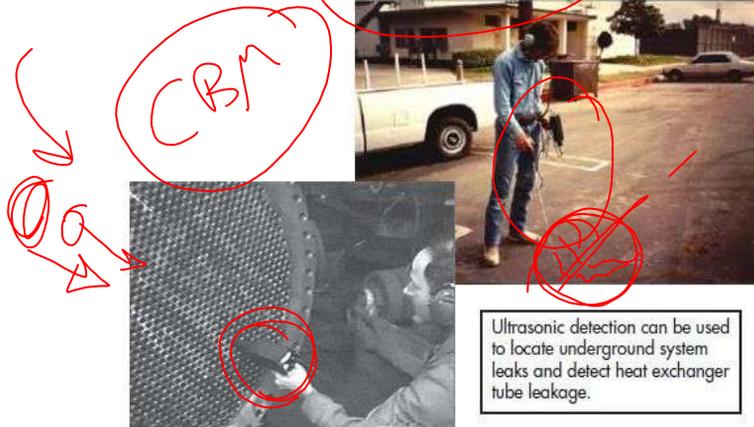


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Condition Based Maintenance: Ultrasonic Inspection



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Condition Based Maintenance: Ultrasonic Inspection

Example Applications



- Mechanical inspection
- Bearings
- Lack of lubrication
- Pumps
- Motors
- Gears/Gearboxes
- Fans
- Compressors
- Conveyers.



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

Condition Based Maintenance: Ultrasonic Inspection



Example Applications



#### Electrical Applications

- Arcing/tracking/corona
- Switchgear
- Transformers
- Insulators
- Potheads
- Junction boxes
- Circuit breakers.

Mechanical devices are not the only sources of ultrasonic emission. Electrical equipment will also generate ultrasonic waves if arcing/tracking or corona are present.

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Condition Based Maintenance: Oil Analysis



Monitoring oil condition warns of an increase in foreign substances, such as water, (>2.5%) which can degrade the lubricating properties of the oil and cause bearing failures. It also detects the presence of metallic particles carried into the oil stream. These metallic particles are analysed to determine which part of the machine is wearing and how fast. Particle Counting and Ferrograph are two analysis techniques.



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Condition Based Maintenance: Oil Analysis



Typical oil analysis equipment available from several different vendors.



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Category	Key Analysis	Analytical Techniques
Machine Wear	Fine wear metals	Rotating Disc Electrode (RDE) Spectroscopy*, Inductive Coupling Plasma (ICP) Spectroscopy
	Large wear metal elements	Rotode Filtration Spectroscopy (RFS)*
	Partice count and distribution	Particle count, LaserNet Fine (LNF)*
	Wear particle shape analysis	LNF*, Ferrography, Wear Debris Analysis (WDA)
Contamination	Sand and Dirt	Particle count, LaserNet Fines (LNF)*
	Fuel Dilution	Fuel Sniffer*, Gas Chromatography (GC)
	Water/Moisture	Infrared (IR)*, Karl Fischer Titration (KF)
	Glycol/Coolant	IR*
	Soot	Soot meter, IR*
	Alien Fluid	IR*
Degradation	Oxidation, Nitration, Sulfation	IR*
	Viscosity	Viscosity*
	Acid number (AN) or Base Number (BN)	Titration, IR*



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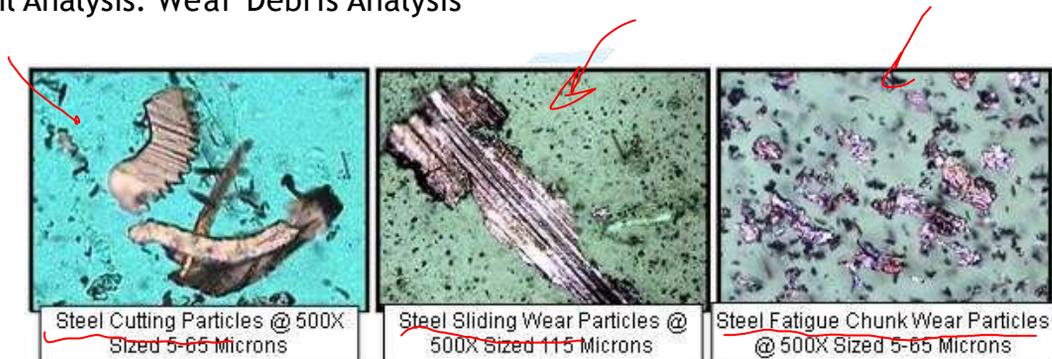
Oil Analysis: Wear Debris Analysis



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

Oil Analysis: Wear Debris Analysis



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#### Motor Current Analysis

- Monitoring the motor current during start-up (surge current) and the current trace over time (decay) to detect friction forces.
- A predictive technique used to analyze current and voltage supplied to an electric motor or generator to detect abnormal operating conditions in induction motor applications.
- Motor current analysis can be used to identify incoming winding health, stator winding health, rotor health, load issues, system load and efficiency, bearing health, air gap static and dynamic eccentricity and coupling health



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

#### Condition Based Maintenance Applications Summary

TECHNOLOGIES	PUMPS	ELECTRIC MOTORS	DIESEL GENERATORS	CONDENSERS	HEAVY EQUIPMENT/CRANES	CIRCUIT BREAKERS	VALVES	HEAT EXCHANGERS	ELECTRICAL SYSTEMS	TRANSFORMERS	TANKS, PIPING
VIBRATION MONITORING/ ANALYSIS	●	●	●		●						
LUBRICANT, FUEL ANALYSIS	●	●	●		●					●	
WEAR PARTICLE ANALYSIS	●	●	●		●						
BEARING TEMPERATURE ANALYSIS	●	●	●		●						
PERFORMANCE MONITORING	●	●	●	●				●		●	



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment



#### Condition Based Maintenance Applications Summary

TECHNOLOGIES	APPLICATIONS	PUMPS	ELECTRIC MOTORS	DIESEL GENERATORS	CONDENSERS	HEAVY EQUIPMENT/CRANES	CIRCUIT BREAKERS	VALVES	HEAT EXCHANGERS	ELECTRICAL SYSTEMS	TRANSFORMERS	TANKS, PIPING
ULTRASONIC NOISE DETECTION		●	●	●	●			●	●	●	●	
ULTRASONIC FLOW		●			●			●	●			
INFRARED THERMOGRAPHY		●	●	●	●	●	●	●	●	●	●	
NON-DESTRUCTIVE TESTING (THICKNESS)					●				●			●
VISUAL INSPECTION		●	●	●	●	●	●	●	●	●	●	●



## Pillar 3 - Equipment Reliability

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#### Condition Based Maintenance Applications Summary

TECHNOLOGIES	APPLICATIONS	PUMPS	ELECTRIC MOTORS	DIESEL GENERATORS	CONDENSERS	HEAVY EQUIPMENT/CRANES	CIRCUIT BREAKERS	VALVES	HEAT EXCHANGERS	ELECTRICAL SYSTEMS	TRANSFORMERS	TANKS, PIPING
INSULATION RESISTANCE			●	●			●			●	●	
MOTOR CURRENT SIGNATURE ANALYSIS			●									
MOTOR CIRCUIT ANALYSIS			●				●			●		
POLARIZATION INDEX			●	●						●		
ELECTRICAL MONITORING										●	●	



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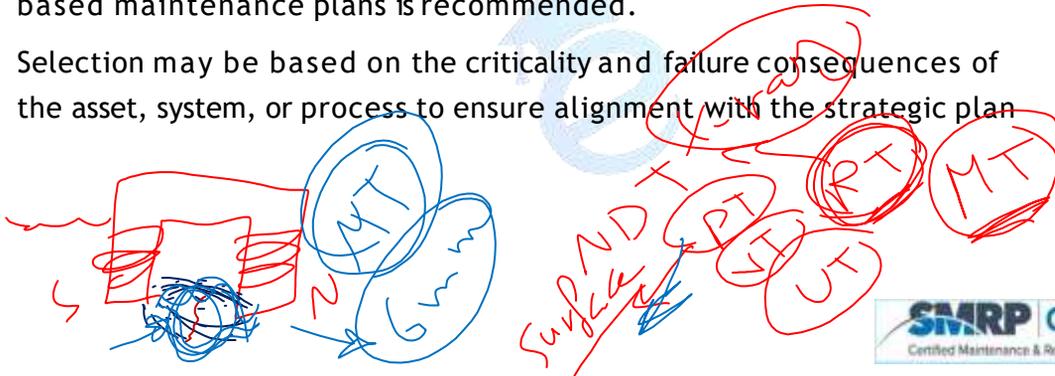
### 3.3 Establish a strategic plan to assure reliability of existing equipment



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The use of one or more processes focused on developing reliability-based maintenance plans is recommended.

Selection may be based on the criticality and failure consequences of the asset, system, or process to ensure alignment with the strategic plan



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Reliability Centered Maintenance (RCM)

- A phrase coined more than thirty years ago to describe a cost effective way of maintaining complex systems.
- The RCM method uses the answers to seven very basic questions to help determine the best maintenance tasks to implement in an Equipment Maintenance Plan (EMP).
- RCM is well-proven technique to enhance reliability and safety, and to optimize the overall maintenance activities performed on site in a cost effective and applicable timeframe.



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### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

Principle 1: The primary objective of RCM is to preserve system function.

Principle 2: Identify failure modes that can defeat the functions.

Principle 3: Prioritize function needs (failures modes).

Principle 4: Select applicable and effective tasks.

1. Prevent or mitigate failure.
2. Detect onset of a failure.
3. Discover a hidden failure.



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Reliability Centered Maintenance (RCM)

RCM is used to determine the maintenance regime that should be applied to plant physical assets using that particular asset's operational context and asset's criticality as the important determining factors.

The RCM results will:

- Concentrate preventive maintenance efforts where they will do the most good
- Eliminate maintenance where the assets can be cost-effectively run-to-failure
- Devise the simplest means of maintaining equipment or testing for degradation



## Pillar 3 - Equipment Reliability

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Reliability Centered Maintenance (RCM)



#### Related Industry Standards

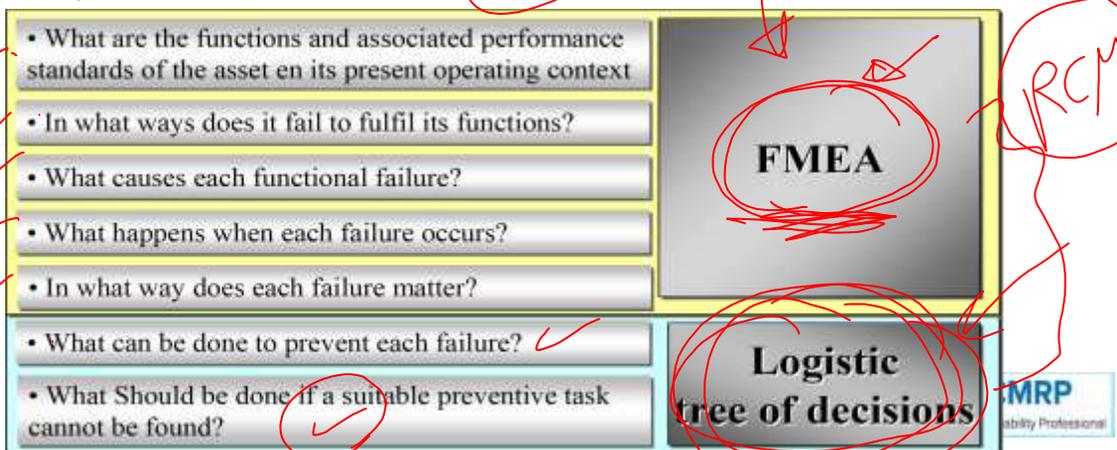
- ISO 14224-2006 Collection and exchange of reliability and maintenance data for equipment
- AE JA-1011, Aug 1999 Evaluation Criteria for Reliability-Centered Maintenance (RCM) Process
- SAE JA-1012, Jan 2002 A Guide to the Reliability-Centered Maintenance (RCM) Standard



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Reliability Centered Maintenance (RCM)



# Pillar 3 - Equipment Reliability

## 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

Example FMEA Sheet with Maintenance Task Decided for Process Pump

Function	Functional Failure	Failure Mode (cause)	Failure effects	Severity			Occ	Det	RPN	Maintenance task	Recommended interval
				S	A	C					
Transfer minimum of 700 L/minute of process liquid from tank A to tank B	Doesn't transfer any liquid	Pump Stuck due to seized bearing	Production line shutdown	1	8	2	5	1	80	Check and Perform Periodical Vibration Analysis	1 Month

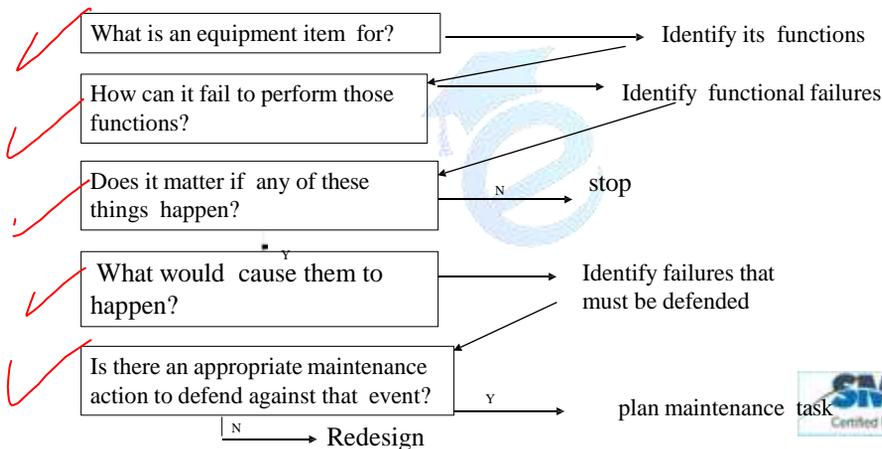
S = Safety  
 A = Environment (accident/Environmental)  
 C = Cost/Production



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## 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

Unlike some other maintenance planning approaches, RCM results in all of the following tangible actionable options:

- Maintenance task schedules, which can include:
  - ✓ ○ Time Directed (TD) tasks, (Calendar/run time based PMs)
  - ✓ ○ Condition Directed (CD) tasks, (CBM/PdM tasks)
  - ✓ ○ Failure Finding (FF) tasks (operator supported tasks)
  - ✓ ○ Run-to-Failure (RTF) tasks (economical decision based)
- Revised operating procedures for the operators of the assets
- A list of recommended changes to the design of the asset



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

RCM shifts the emphasis of maintenance from the idea that all failures are bad and must be prevented, to a broad understanding of the purpose of maintenance.

- It seeks the most effective strategy that focuses on the performance of the organization.
- It might include not doing something about a failure or letting failures happen.
- The RCM approach encourages us to think of more encompassing ways of managing failures.



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

#### Reliability Centered Maintenance (RCM) - Benefits

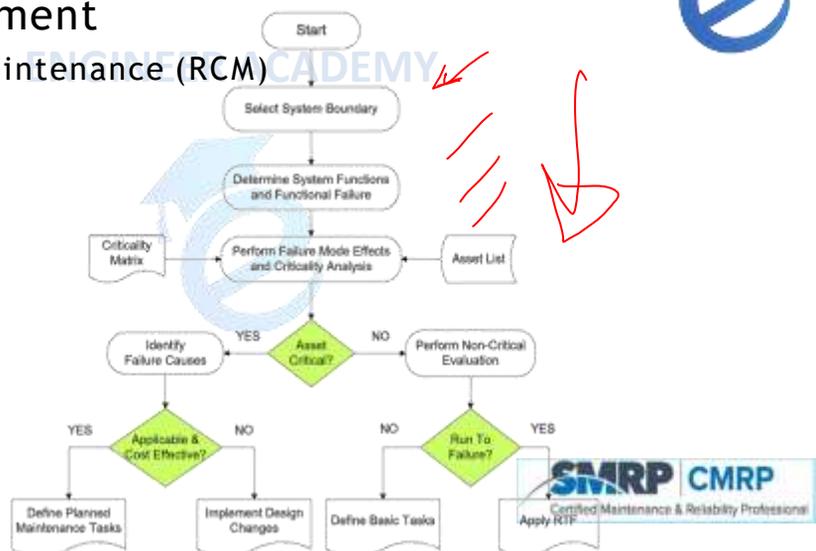
Reliability:	<ul style="list-style-type: none"> <li>The primary goal of RCM is to improve asset reliability and availability cost-effectively.</li> </ul>
Cost.	<ul style="list-style-type: none"> <li>A new RCM program typically results in a short-term increase in maintenance costs.</li> </ul>
Documentation.	<ul style="list-style-type: none"> <li>Understanding and documentation of operations and maintenance key features, failures modes, basis of PM tasks, related drawings and manuals, etc.</li> </ul>
Equipment/Parts	<ul style="list-style-type: none"> <li>Another benefit of RCM is that it obtains the maximum use from the equipment or system.</li> </ul>
Efficiency/Productivity.	<ul style="list-style-type: none"> <li>Second most important concern is cost effectiveness, which takes into consideration the priority or mission criticality and then matches a level of cost appropriate to that priority.</li> </ul>

## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

#### Reliability Centered Maintenance (RCM)

RCM flow diagram



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

RCM project phases



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

#### Criticality Analysis

Criticality – A relative measure of the consequences of a failure and its frequency of occurrence.

Criticality analysis (CA) – A procedure by which each potential failure mode is ranked according to the combined influence of severity and probability of occurrence.



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM)

#### Criticality Analysis

Method of Criticality based of Risk Concept:

$$\bullet \text{ Risk} = \text{Frequency} \times \text{Consequence}$$

Frequency = # of faults during a specific time period

$$\text{Consequence} = (\text{Operational Impact} \times \text{Flexibility}) + \text{Maintenance Costs} + \text{Impact On Safety/Environment}$$

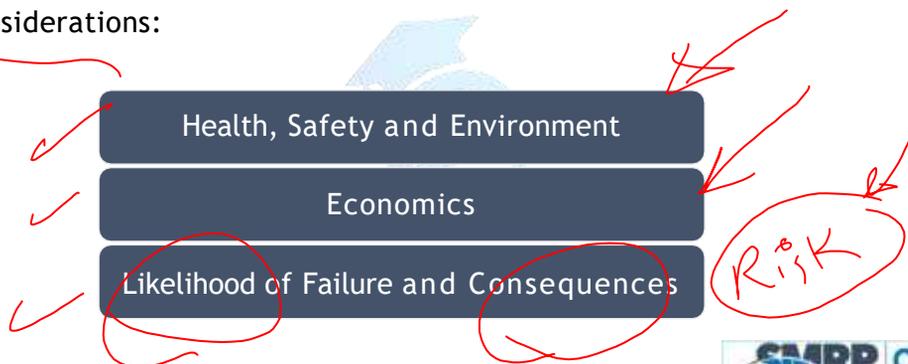


## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM), Criticality Analysis

Criticality Considerations:



## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM), **Criticality Analysis**

The consequence categories are:

<b>Health &amp; Safety Consequences</b>	• A failure has health or safety consequences if there is an intolerable probability that it could kill or injure a human being.
<b>Environmental Consequences</b>	• If there is an intolerable probability that it could breach any known environmental standard or environmental requirements for emission and effluents.
<b>Economics Consequences</b>	• The magnitude of these effects depends on how heavily the equipment is utilized and the availability of alternatives.
<b>Reputation</b>	• A failure has created public awareness or disturbance on day to day life of other company or personnel if there is an intolerable probability that it could breach public relation.

## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM), **Criticality Analysis**

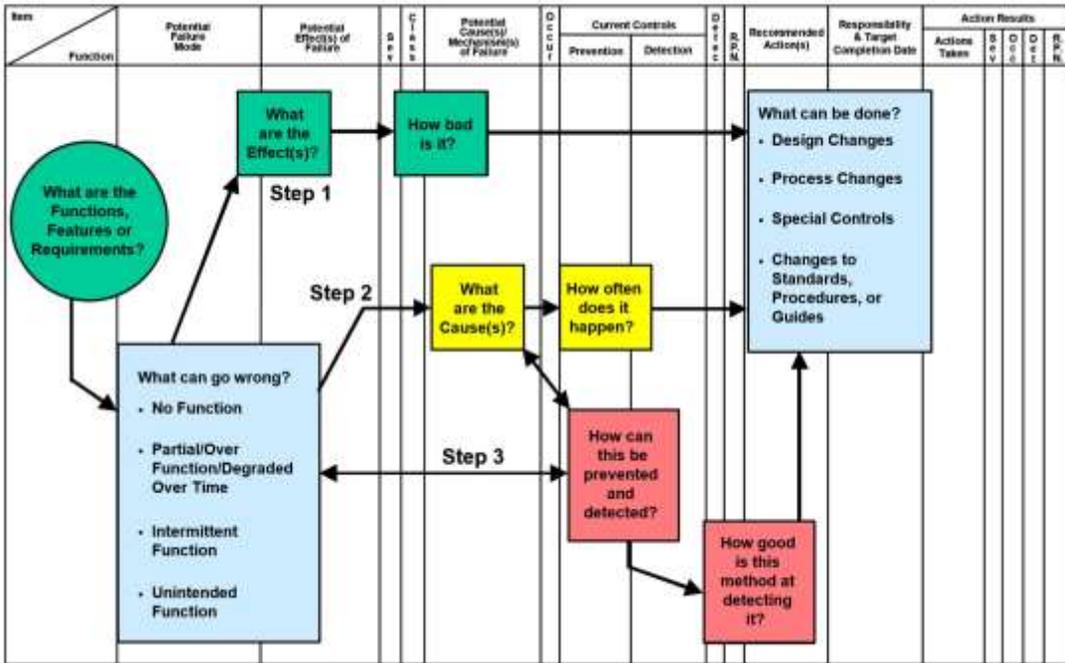
**Criticality Model** = Failure Frequency x Consequence

$$\text{Consequence} = (\text{Operational Impact} \times \text{Flexibility}) + \text{Maint. Costs} + \text{SE Impact}$$

<b>Failures Frequency:</b> Bad: > 4 failures/year      4 Average: 2 - 4 failures/year      3 Good : 1 - 2 failures/year      2 Excelent: < 1 failures/year      1	<b>Maintenance Costs:</b> > 20.000\$      2 < 20.000 \$      1
<b>Operational Impact</b> Total stop of the complex      10 Partial stop (plant)      6 Quality impact      4 Operational Cost for unavailability      2 Not impact      1	<b>Security/Environment Impact</b> Human Security impact      8 Catastrophic Environment Impact      6 Major damage to the installation      4 Minor damage (Incidents)      2 Non impact      0
<b>Flexibility</b> There are not spare      4 There are spare in store      2 There are function spare      1	





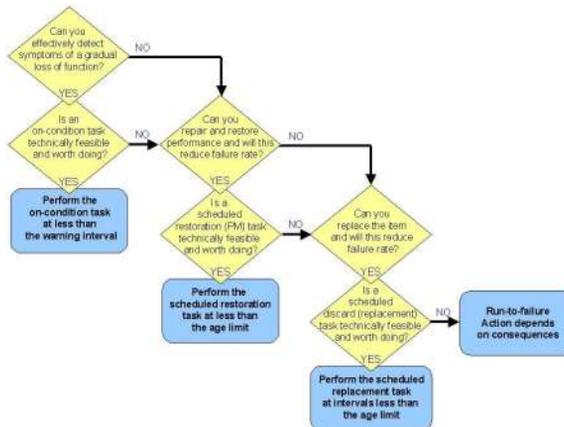


## Pillar 3 - Equipment Reliability

### 3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM),

Task Selection Decision Tree

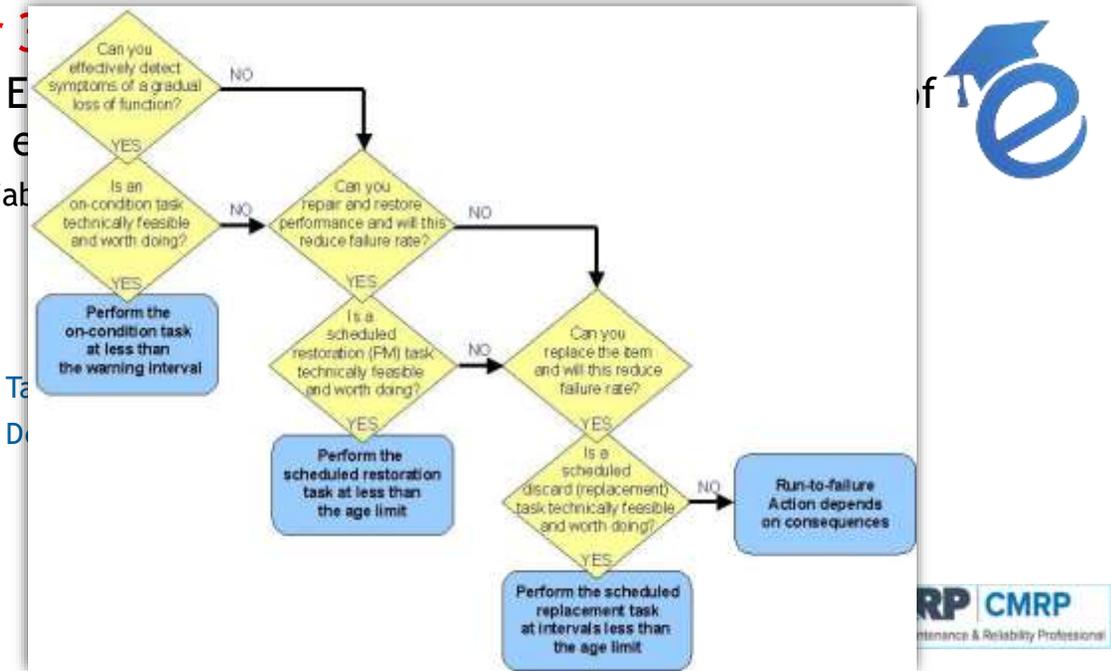


Pillar 3

3.3 E

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Reliab



Pillar 3 - Equipment Reliability

3.3 Establish a strategic plan to assure reliability of existing equipment

Reliability Centered Maintenance (RCM),

It is important to perform periodic reviews of these plans and equipment reliability performance, and to make adjustments as :

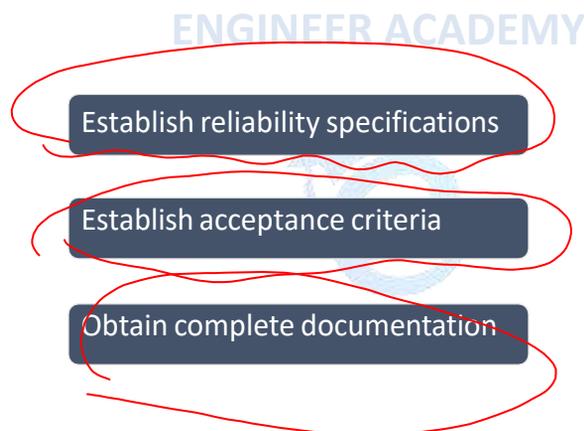
- Business needs
- Performance needs
- Requirements change.

PMO



## Pillar 3 - Equipment Reliability

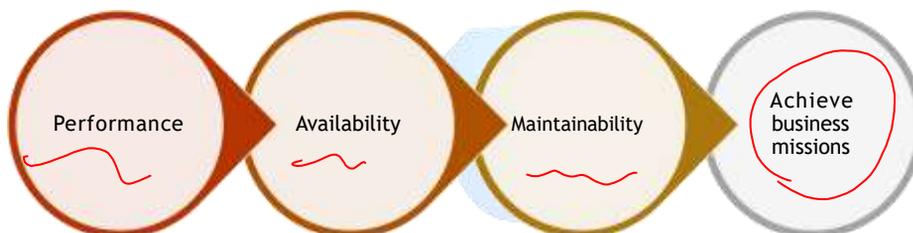
### 3.4 Establish a strategic plan to assure reliability of new equipment



## Pillar 3 - Equipment Reliability

### 3.4 Establish a strategic plan to assure reliability of new equipment

An equipment reliability strategy is developed using defined:



These requirements are translated into reliability specifications and acceptance criteria, including documentation requirements, for use in procuring equipment.

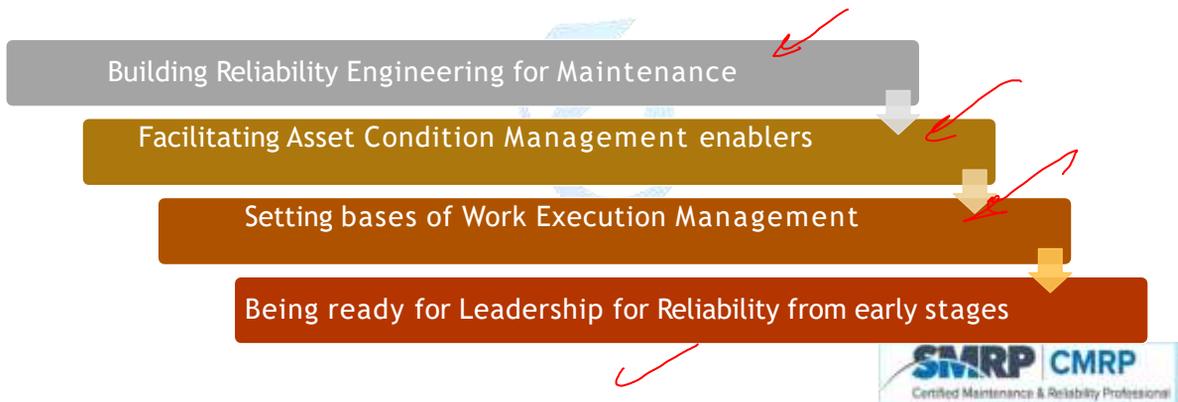
They also provide specific guidance for use in the maintenance planning process.



## Pillar 3 - Equipment Reliability

### 3.4 Establish a strategic plan to assure reliability of new equipment

What is needed for new plant, unit or asset



## Pillar 3 - Equipment Reliability

### 3.4 Establish a strategic plan to assure reliability of new equipment

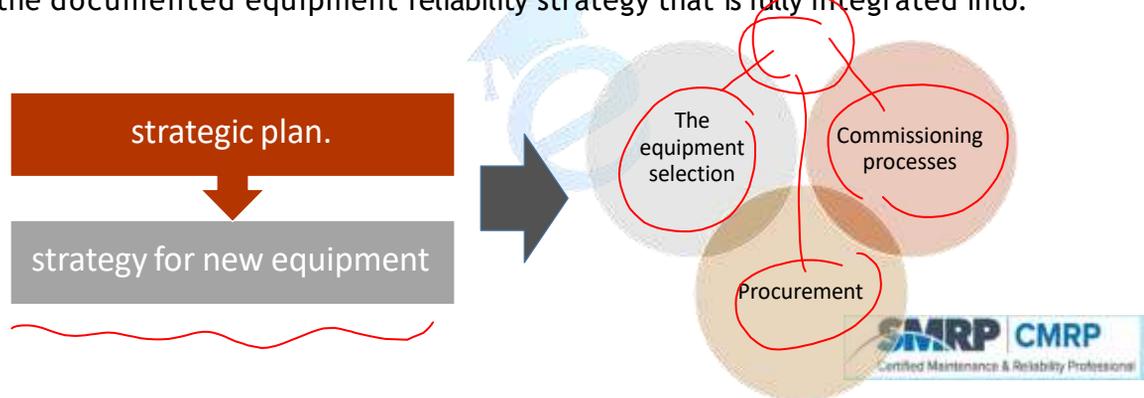
This includes:

- Setting reliability requirements & expectations.
- Setting maintainability requirements and specifications.
- Building Asset Register & Information.
- Specifying required asset condition information.
- Specifying asset condition monitoring requirements and related specifications.
- Setting machinery lubrication & oil analysis requirements.
- Building maintenance philosophy and strategy (including conducting RCM).
- Preparing computerized work management system (CMMS)

## Pillar 3 - Equipment Reliability

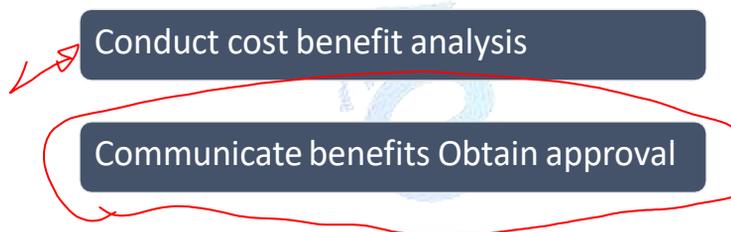
### 3.4 Establish a strategic plan to assure reliability of new equipment

The essential first step in assuring reliability over the life of the equipment is the documented equipment reliability strategy that is fully integrated into:



## Pillar 3 - Equipment Reliability

### 3.5 Cost-justify selected plans for implementation



## Pillar 3 - Equipment Reliability

### 3.5 Cost-justify selected plans for implementation

#### Cost Benefit Analysis

