Reliability Centered Maintenance

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Topics

I. What is RCM
II. History of RCM
III. RCM at NASA
IV. RCM Analysis
V. Maintenance Tasks
VI. Predictive Technologies

What is RCM ?

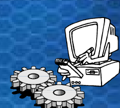
Process **… for determining the**

best maintenance

to achieve

design reliability at minimum cost

The Basis For RCM



RCM is derived from a careful consideration of…

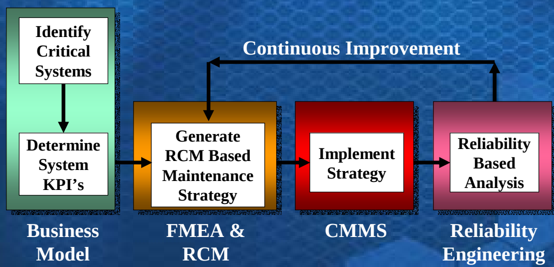
1. What does the asset do? "Function"
2. How can the asset fail to fulfill its functions ?
3. What causes each functional failure ?
4. What happens when each failure occurs ?
5. What are the consequences of failure?
6. What should be done to mitigate the consequences of these failures ? (tasks and intervals)
7. What should be done if no task can be found ?

Benefit of RCM

Promotes a "proactive" maintenance program

Instead of a typical "reactive" program

"Big Picture" Vision of Asset Management



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History of RCM

The traditional approach to scheduled maintenance . . .

is based on the concept that every part of complex equipment has a "right age" at which complete overhaul is necessary to ensure safety and operating reliability.

Through experience . . .

it was discovered that many failures could not be prevented regardless of how much maintenance was performed.

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History of RCM

In the late 1950's,
failure to control the reliability of certain engines in the commercial airline industry . . .

led the FAA to form a task group to investigate the capabilities of preventive maintenance.

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History of RCM

Three Significant Discoveries Were Made . . .

- Scheduled overhaul had little effect on the overall reliability of a complex item unless the item has a dominant failure mode.
- There were many items for which there is no effective form of scheduled maintenance.
- Cost reductions in maintenance could be achieved with no decrease in reliability. A better understanding of the failure process in complex equipment has actually improved reliability by making it possible to direct preventive tasks at specific evidence of potential failures.

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History of RCM

- 1960 FAA Scheduled Maintenance Investigation - MSG 1 and MSG 2
- 1970's Adopted by US Navy
- 1980's Industry starting to Implement
- 1990's NASA Facility Implementation Program

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The Three Basic Maintenance Strategies

- **Run- To- Failure**
  (Breakdown or Corrective)
- **Fixed Frequency (PM)**
  (Time Based)
  (Opportunity Based)
- **Condition Based – (Predictive, PdM)**
  (Based on Condition Monitoring)

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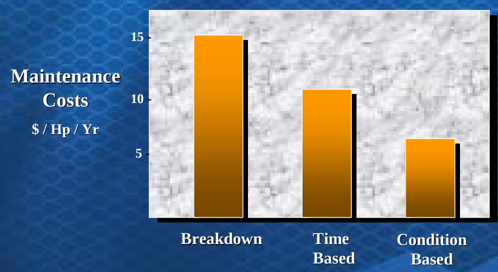
Basic Maintenance Strategies

Comparison of Maintenance Costs



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Strategy #1 - Run-To-Failure

ADVANTAGES	DISADVANTAGES

ADVANTAGES

- **No downtime between failures**
- **Traditionally accepted by maintenance personnel "don't fix unless broke"**
- **Easy to justify to outside groups**
- **Promotes the quick fix hero syndrome**

DISADVANTAGES

- **Large spare parts inventories**
- **Quick response required from trained personnel**
- **Unscheduled work outages**
- **Longer restoration time**
- **Higher restoration costs**
- **Low manageability of budget, personnel and parts**
- **Disregards safety**
- **Possible collateral damage**

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Strategy #2 - Time Based Maintenance

ADVANTAGES

- Reduces risk of catastrophic failure
- Prevents equipment failure
- Overcomes, to some extent, the disadvantages of Run-to-Fail

DISADVANTAGES

- Operating time per cycle is reduced
- Costly unneeded maintenance is performed
- Condition-based maintenance is not identified
- Operational restrictions result in deferred maintenance
- Frequency intervals based on limited data and vendor recommendations

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Strategy #3 - Condition Based Maintenance

ADVANTAGES

- Provides for continuous risk assessment
- Integrates with total resource planning
- Accounts for all the disadvantages of Run-to-Fail and Fixed Frequency

DISADVANTAGES

- Higher implementation and operating costs for labor and condition monitoring system
- Higher commitment to technical training or vendor services.

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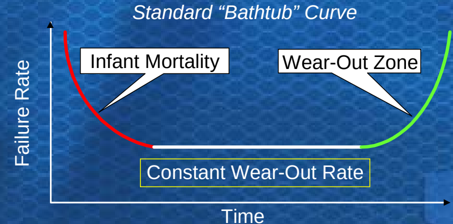
Traditional View of Equipment Life

Standard "Bathtub" Curve



The traditional approach to maintenance is based on a misunderstanding of failure distributions. Only a small percentage of equipment follows this curve

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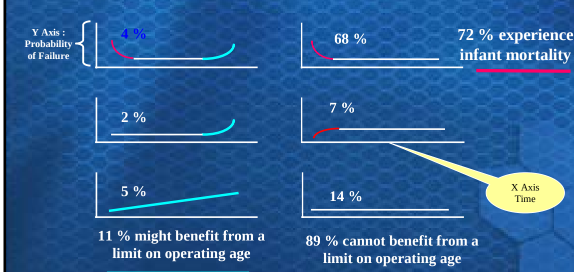
6 Patterns of Degradation/ Failure



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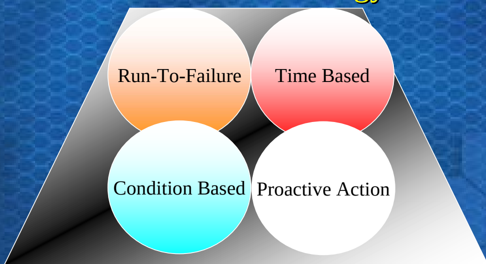
Which Maintenance Strategy to Use



Reliability Centered Maintenance

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Proactive Maintenance Techniques

- Specifications for new/rebuilt equipment
- Precision rebuild and installation
- Failed-part analysis
- Root-cause failure analysis
- Reliability engineering
- Rebuild certification/verification
- Age exploration
- Recurrence control

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Predictive Technologies

- Vibration Analysis
- Infrared Thermography
- Ultra Sonic Detection
- Oil Analysis
- Electrical System Analysis

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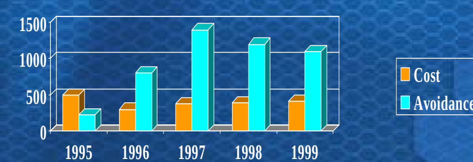
GRC PT&I Benefit/Cost Analysis



NASA had greater than 3,000 PT&I finds agency-wide.

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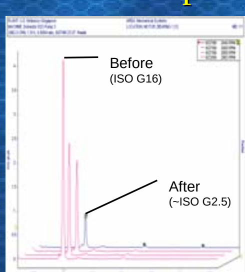
Pump Vibration



Pump Vibration

Domestic H_2O Pumps

Before & After Balancing

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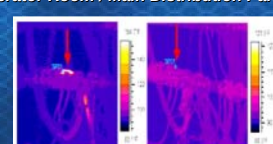
Infrared Thermography

Generator Room / Main Distribution Panel



Elevated temperature on a neutral wire caused by loose connection. IR image on right is after repair - tightening of connection

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Airborne Ultrasonics

Electrical Uses

Corona, Tracking and Arcing

Mechanical Uses

Gas Leaks
Fluid & Steam Leaks
Steam traps

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Air Leaks

Leaks create turbulence which generate frequencies detectable in the 40 kHz range as eddy currents develop as air flows out an orifice.

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Lubricant Analysis / Fluid Analysis

- **Visual and Odor**
- **Viscosity**
- **Water**
- **Percent Solids/Water**
- **Particle Counting**
- **Total Acid Number (TAN)**
- **Total Base Number (TBN)**
- **Spectrometric Metals**
- **Spectrometric Metals**
- **Infrared Spectroscopy**
- **Direct-Reading (DR) Ferrography**
- **Analytical Ferrography**

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Electrical Tests

Electrical Equipment	Power Factor Tests	Excitation Tests	Insulation Resistance	Infrared	Ultrasonic	Battery Impedance	Breaker timing	Insulating Oil	Partial Discharge	Contact Resistance	High Voltage Testing	Motor Circuit Analysis	Turns Ratio Tests	Dissolved Gas Analysis
Transformers	●	●	●	●	●			●					●	●
Circuit Breakers	●		●	●	●		●	●		●	●	●		
Motors	●		●	●					●		●	●		
Batteries				●		●								
Motor Control Centers			●	●	●							●		
Switchgear	●		●	●	●					●	●			
Power Panels			●	●	●									
Power Cables	●		●						●		●			

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Summarizing the RCM Process

- Systematic
- Safety and Environmental consequences are addressed up front.
- Concerned with mitigating the consequences of failure, and not with eliminating failure
- Focused on preserving system function
- Uses condition monitoring technologies when appropriate to reduce the effects of "infant mortality"

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Back-Ups
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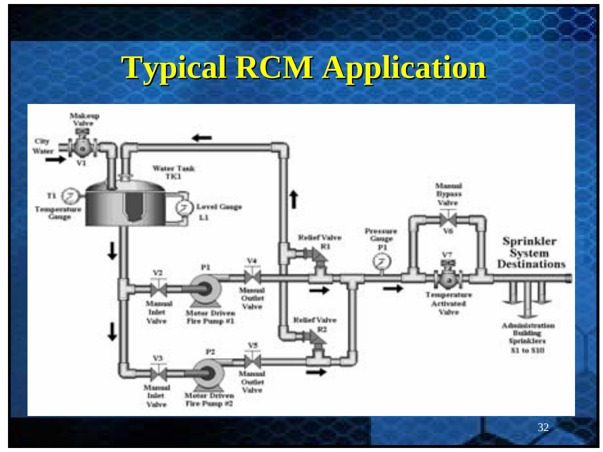
Typical RCM Application
Sprinkler System Destinations
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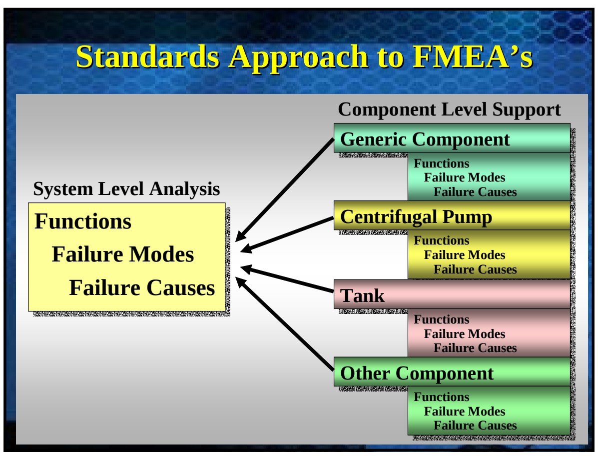
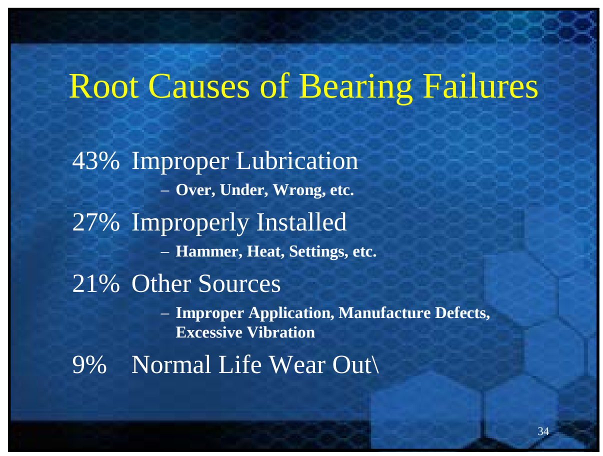

Standards Approach to FMEA's
Component Level Support
System Level Analysis
Functions
Failure Modes
Failure Causes
Generic Component
Functions
Failure Modes
Failure Causes
Centrifugal Pump
Functions
Failure Modes
Failure Causes
Tank
Functions
Failure Modes
Failure Causes
Other Component
Functions
Failure Modes
Failure Causes


Root Causes of Bearing Failures
43% Improper Lubrication
– Over, Under, Wrong, etc.
27% Improperly Installed
– Hammer, Heat, Settings, etc.
21% Other Sources
– Improper Application, Manufacture Defects, Excessive Vibration
9% Normal Life Wear Out\
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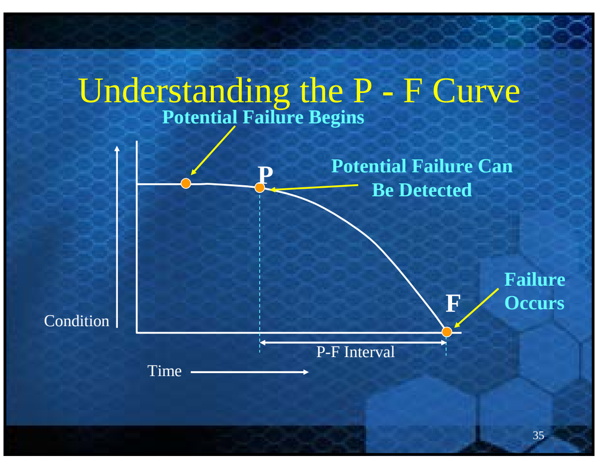
Understanding the P - F Curve
Potential Failure Begins
P
Potential Failure Can Be Detected
F
Failure Occurs
Condition
P-F Interval
Time
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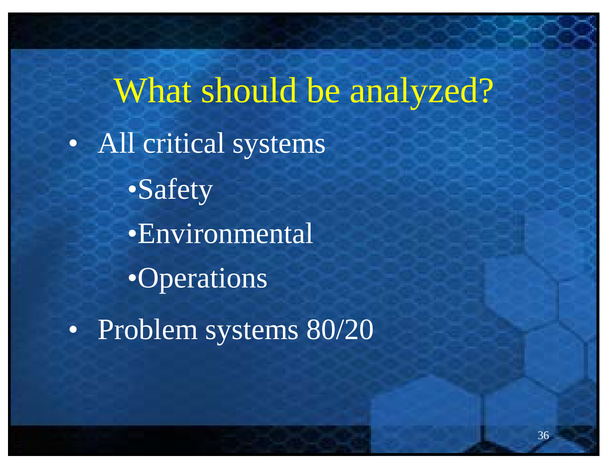
What should be analyzed?
• All critical systems
•Safety
•Environmental
•Operations
• Problem systems 80/20
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Operating Context

Defines and describes the exact circumstances under which an asset is to be used.

Which typically includes :

- Why it exists
- Where it is to be used
- How it is to be used
- Overall performance criteria governing issues such as output, throughput, safety, environmental integrity, etc.

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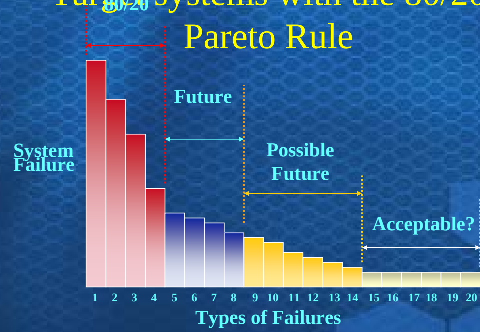
Target systems with the 80/20 Pareto Rule



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Selecting the system size for the analysis!

- Maximum analysis size is roughly 40-60 major components.
- Major components are MCC's, pumps, compressors, chillers etc…
- Lower component count for highly automated systems.
- To high – To vague!
- To low – Analysis Paralysis!
- Black box – Possible future analysis or needs further review.

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Defining the system for the analysis!

- Need a physical description
  - •Design information
  - •What does the user want the system to provide
- Need to define the boundaries
  - •What is included
  - •What is not included
- Need to define input and output interfaces
  - •What external inputs affect our system
  - •What internal outputs does our system create

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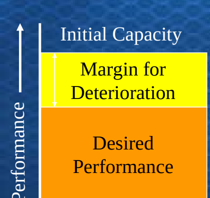
Performance Standards

Shall be the level of performance desired by the owner or user of the asset (or system) in its operating context.



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Maintenance Decisions

What should be done to reduce the risks and consequences of failure ?

- Decision support diagrams
  - •Hidden or Evident?
  - •Types of maintenance tasks
  - •Consistent approach
- Determine the frequency of a task

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Hidden Failures

- Some failure modes occur in such a way that nobody knows that the item is in a failed state unless, or until, some other failure (or abnormal event) also occurs.
- Hidden failures can account for up to half the failure modes that could affect modern, complex equipment, so they need to be handled with special care.
- Requires a statistical approach to identify the task frequency

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