RCM
Reliability Centered Maintenance

versus

PMO
Preventative Maintenance Optimization

Alan Neesley
Six Sigma Black Belt

The Changing World of Maintenance 1775 -1957

G Harry Stine wrote a column in 1957 called **Sputnik: One Reason We lost**

How did the Russians beat the US into space with a satellite?

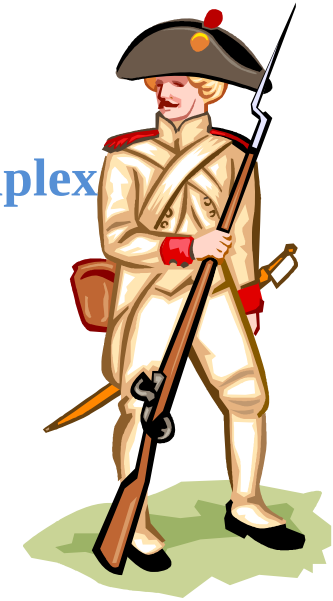
American perfectibility was the belief in 1830, but in 1776:

- **2,500,000 people spread over Atlantic coast**
- **>300 men in all 13 colonies had been to college**
- **>1/2 the towns in Massachusetts had schools**

The fear of the Wilderness made them the most pragmatic people in history- no scientists, no craftsmen, no engineers so they developed Yankee Ingenuity

There were no engineering colleges until after the Civil War!

1. **Pragmatic approach worked for the wilderness, not more complex equipment**
2. **Historical lack of appreciation of science itself**
3. **Science is spoiled, must be complex to get results**
4. **The Team has killed the individual approach**



The Changing World of Maintenance 1900 -1940

The first **assembly line** was not by Henry Ford, but in 1901 by Eli Olds (Oldsmobile). This mentality "drives" maintenance thinking

http://www.enchantedlearning.com/inventors/1900a.shtml

First Generation Maintenance

Industry not highly mechanized
Equipment simple and overdesigned
Easy to repair
Downtime not important
Fix it when it broke

RCM II by John Moubray

Shewhart starts statistical revolution on quality control of electronic products

1910 Canning Factory

The Changing World of Maintenance 1940-1975

World War 2 changes the world. Demand for goods increases while the supply of manpower drops sharply.

Maintenance planning and control systems

RCM II by John Moubray

Second Generation Maintenance

Increased mechanization
Equipment more complex and more of them
More money tied up in assets
Downtime more important
Preventative maintenance
– overhauls at fixed intervals
Many business seasonal,
so done during off season
Big slow computers

The Changing World of Maintenance 1975 -present

Technological advances, environmental and safety regulations and high energy costs drastically change manufacturing

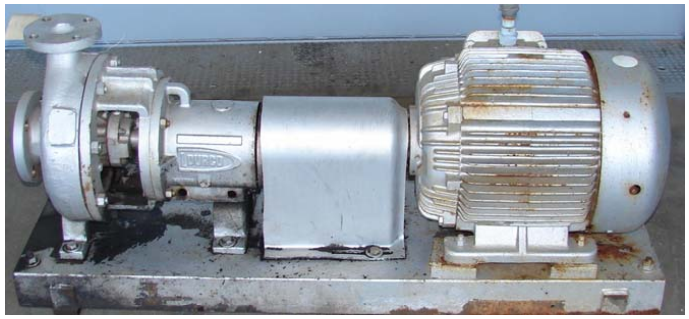
Third Generation Maintenance

Condition monitoring
Design for reliability and maintainability
Hazard studies
Small fast computers
FMEA
Expert systems
Multi-tasking and teamwork

RCM II by John Moubray

Fourth generation?

You have a pump that is experiencing a seal failure every 60 days. It causes three hours of downtime and affects product quality. It is a single seal and the material, if released, constitutes a spill to the environment.



(Note any resemblance of this example to any real life situation is purely coincidental.)

Example – Recurring seal failure

What do you do?

Replace seals when they fail

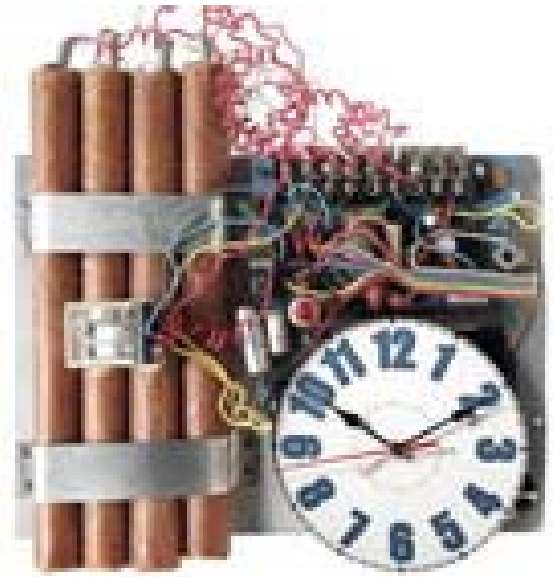
Reactive decision

- **Downtime**
- **Quality issues**
- **Environmental issues**

Example – Recurring seal failure

What do you do?

Replace seals periodically
(time based)



Preventive Maintenance

- **Minimize downtime**
- **Reduce quality problem**
- **(If installation problem, failures will increase!)**

Example – Recurring seal failure

What do you do?

Replace when the impending failure is detected

Predictive Maintenance

- **Reduces downtime**
- **Reduces quality issues**
- **Reduces cost (less than periodic)**

(If installation problem, failures will increase!)

Example – Recurring seal failure

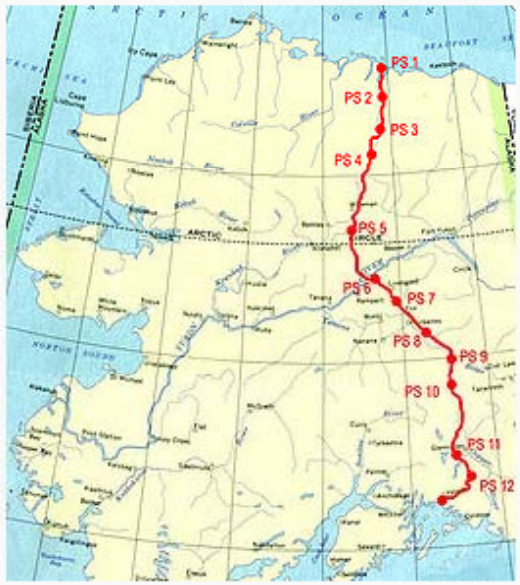
What do you really want to do ?

Understand what went wrong and fix it!
Prevent reoccurrence

For example see Rebecca Porche's presentation on Root Cause Analysis on the section website (12/12/2007)

Alaska Pipeline Failure 2006

The Trans-Alaska Pipeline



Map of Trans-Alaska Pipeline

March 2, 2006

Oil Leak Discovered by BP in Trans-Alaskan Pipeline (TAPS) 200,000 gallons

March 15, 2006

DOT orders Corrective action Order to "smart pig"

Found numerous problems and leaks

Two criminal investigations are underway

http://energycommerce.house.gov/index.php?option=com_content&view=article&id=868&catid=67&Itemid=58

http://en.wikipedia.org/wiki/Trans-Alaska_Pipeline_System

Alaska Pipeline Failure 2006

More data has been released concerning the Alaskan oil pipeline leak that shut down a major portion of the Prudhoe Bay oil field on the Alaskan North Slope

It appears that **BP changed their pipeline PM requirements based on the history of failures, then did not check to see if this new schedule was working correctly.** After years of running a pig through the pipeline at fairly close intervals to clean the pipes, they decided to stop the cleaning and only conduct **spot ultrasonic testing** of the piping instead. Another pig inspection and cleaning was slated for next year (9 year interval), but leaks were found last month that required the shutdown. The company now plans to replace **16 miles of deficient piping.**

- **What the possible modes of failure are when developing a maintenance plan?**
- **Tailor your preventive maintenance to target the most likely failures**.

http://www.taproot.com/blog/2006/09/alaska_pipeline_failure_1.html

April 10, 1963

- Sank
- 129 lives lost
- Nuclear powered submarine (S5W)
- Performing deep sea diving tests
- Failure of recently installed component
- Ballast tank design flaws
- Subsafe program

USS Thresher (SSN 593)

May 22, 1968

USS Scorpion (SSN 589)

- **Sank**
- **99 lives lost**
- **Nuclear powered submarine (S5W)**
- **Performing submarine warfare simulations**

Subsafe program bypassed

- **Emergency repairs only on February 1, 1967**
- **Subsafe caused overhauls to go from 9months to 36 months**
- **No official cause has ever been determined**

1978 F Stan Nowlan and Howard Heap

- **Published Reliability Centered Maintenance**
- **Commercial aviation needed something different**
  - **Boeing 747 Preventative maintenance program was expected to be 3x as large as the PM program for a 707.**

Airline programs can't be bypassed

How to be economically viable and meet safety standards?

STUDY FAILURES

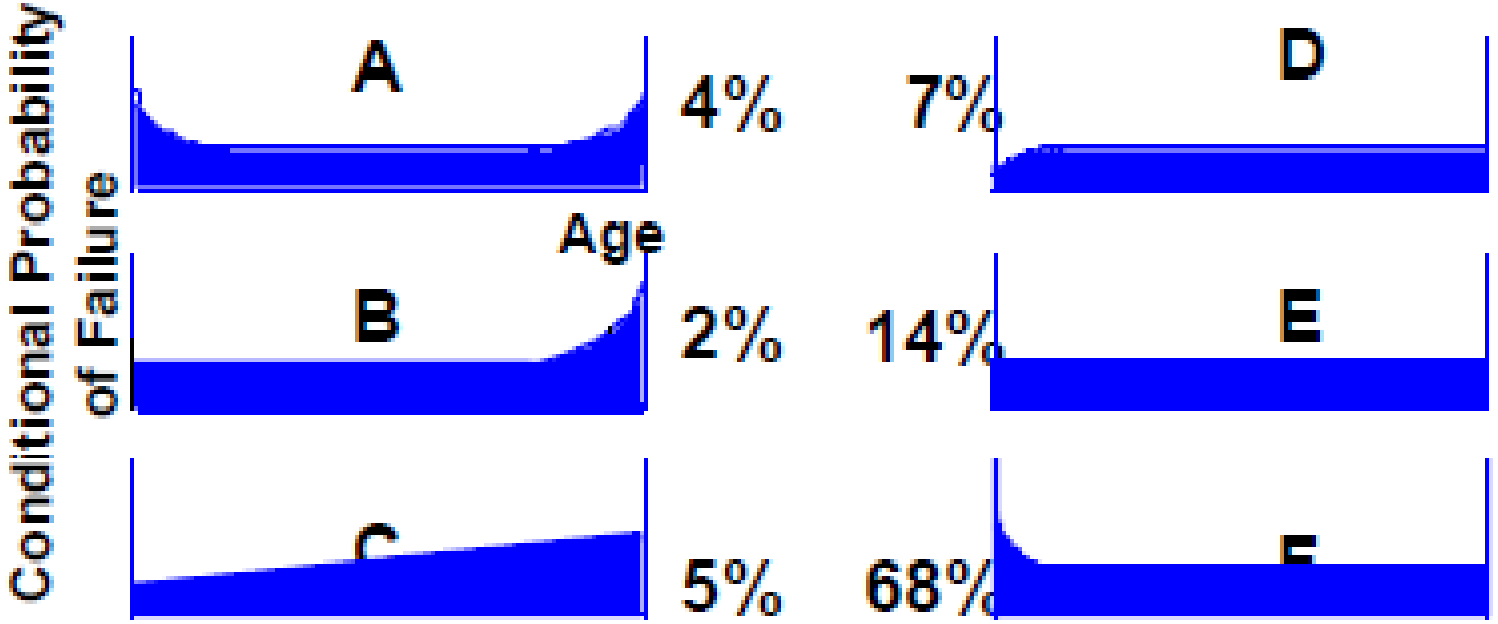
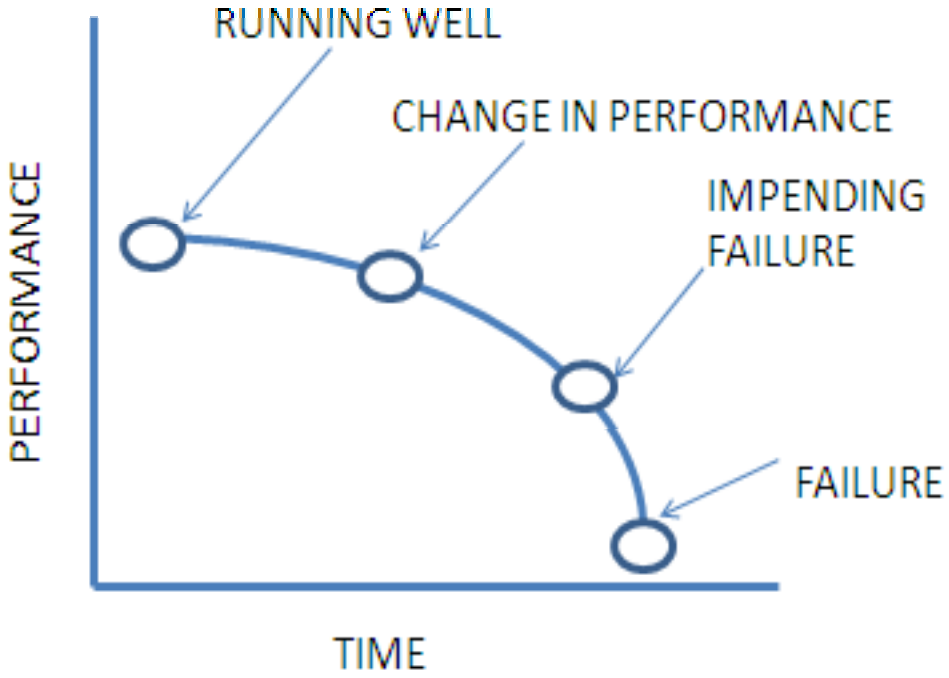


Figure 1 Failure patterns found by Nowlan and Heap 1978

Only about 15% - 20% of equipment failures are age related.

Condition based maintenance



P-f curve

During the normal life period a failure may occur at any time (random), so looking for indicators of failure (conditions) was another approach. This is a p-f curve.

Most failures do not just happen- there are some changes or warning signs such as a new noise, minor leak, or hot spot.

Reliability Centered Maintenance (RCM)

- Nolan and Heap (1978)
- Used in the **design phase** of an asset life cycle.

RCM is undertaken by a cross-functional team (Production, maintenance, process). It is very time consuming, especially the first step (30% of the analysis time). If you are looking at a new piece of equipment, this is a recommended approach.

RCM was and is applied to the airline industry.
Non-rigorous methods were applied to US nuclear plants and submarines

- Focus on reducing maintenance workload

If you have a hammer, everything looks like a nail.

I think of RCM like a **HAZOP** it requires a great deal of time and effort, but for the correct application, it is well worth it.
Since most equipment is familiar pumps, pipes, heat exchangers etc, my guess is it should be used on 4% of your equipment.

Reliability Centered Maintenance (RCM)

Seven questions:

1. What are the functions and desired standards of performance of the asset in its present operating context?
2. In what ways can it fail to fulfil its functions? **functional failures**
3. What causes each functional failure? **failure modes**
4. What happens when each failure occurs? **failure effects**
5. In what way does each failure matter?
6. What should be done to predict or prevent each failure? **proactive tasks and task intervals**
7. What should be done if a suitable proactive task cannot be found? **default actions**

From : Steve Turner's 3 part article series "Maintenance Analysis of the Future"

Planned Maintenance Optimization (PMO)

- Used for existing equipment with known history
- Review of current preventive/predictive maintenance

PMs or planned maintenance are tasks designed to improve overall reliability of a piece of equipment.

A simple example is changing the oil in your car.
You can change it every 3,000 miles or not change it and let it become sludge and have your car fail prematurely.

PMO or PM Optimization is a systematic approach to reviewing a PM program.

Seven questions:

1) What maintenance tasks are being undertaken by the operations and maintenance personnel? **task compilation**

2) What are the failure modes associated with the plant being examined? **failure mode analysis**

a) What is (are) the failure mode(s) that each existing task is meant to prevent or detect

b) What other failure modes have occurred in the past that have not been listed or have not occurred and could give rise to a hazardous situation.

3) What functions would be lost if each failure were to occur unexpectedly (functions)? [optional question]

4) What happens when each failure occurs? **failure effects**

5) In what way does each failure matter? **failure consequences**

6) What should be done to predict or prevent each failure? **proactive tasks and task intervals**

7) What should be done if a suitable proactive task cannot be found? **default actions**

From : Steve Turner's 3 part article series "Maintenance Analysis of the Future"

What do we mean by tasks?

A task is any planned action from an operator making rounds to bringing an outside expert with expensive equipment.

Typical maintenance tasks:
Vessel inspections, ultrasonic thickness readings, infrared temperature measurements, vibration monitoring, lubrication sampling and analysis, calibration of meters,

Advantages and disadvantages:

1.) **PMO** can be **faster** than **RCM**.

Especially for common equipment such as pumps or heat exchangers

2.) RCM like HAZOPs is a rigorous approach that generates many failure modes that are not significant (best use of time and manpower?)

3.) RCM is a cross functional analysis and requires more technical people to perform the analysis. (best use of time and manpower?)

4.) PMO should not be thought of as all inclusive. New failure modes will not typically be generated. Think of it like a forecast, it is based on prior knowledge, not a brainstorming session.

Some thoughts/comments on condition based maintenance:

- As part of a mechanical integrity program, equipment is prioritized into different levels of criticality. The criticality should always be considered in the analysis

.

- Predicting a failure and scheduling a repair will save money. The much larger savings will be derived from a detailed failure analysis and determining how to avoid the failure in the first place.

    1)Managers identify with firefighting and won't appreciate avoidance unless you sell it!

    2)Learn from other's problems. Discuss related safety problems. Talk with manufacturers!

RCM and PMO

Functional

- Both create a systematic maintenance plan
- RCM was developed for the design stage
- PMO is based on experience

Methodology

- RCM is an in depth analysis (HAZOP)
- PMO reviews the current maintenance (What IF)

A simple format for reviewing Maintenance PMs

BOM's C&I Inspections: Type and frequency

Vibration Monitoring: Frequency (Ex: bi-weekly, monthly, quarterly, etc).

Ultrasonic: Frequency (Ex: bi-weekly, monthly, quarterly, etc).

Infrared: Frequency (Ex: bi-weekly, monthly, quarterly, etc).

Lubrication Sampling: Frequency (Ex: bi-weekly, monthly, quarterly, etc). Insert

Lubrication Change: Frequency (Ex: bi-weekly, monthly, quarterly, etc).

Lubrication Grease: Frequency (Ex: bi-weekly, monthly, quarterly, etc).

Other Inspections:

PM Plans: D, W, BW, M, Q, 6M, 12M, 18M, 24M, OTH.
More than one can be used.

PM Checklist: D, W, BW, M, Q, 6M, 12M, 18M, 24M, OTH.
More than one can be used.

Comments: Insert any miscellaneous comments you would like in this box.

3-Year Reliability Results

- Reduction in Reactive Work: 51% ↑
- Reduction in Reactive Maintenance Costs: 28% ↑
- Reduction in Maintenance Overtime: 15% ↑
- Improvement in Mtce % Repl't Value: 4% ↑
- Reduction in Pump Costs: 35% ↑
- Improved Mech Seals MTBF: 133% ↑

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Predictive Maintenance (PdM)

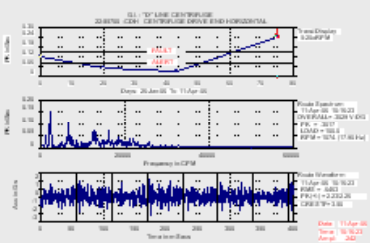
Vibration Monitoring
- 1,536 Machines Monitored
- 200+ Special Checks/Year

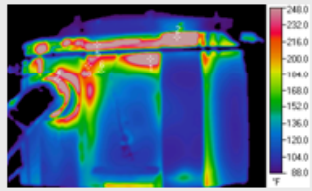
Oil Analysis
- 200 Machines Monitored
- Baselines and Special Checks

Infrared Inspection
- Electrical Equipment - MCC's, High Voltage
- 7 High Temperature Machines Monitored – Boilers, TO's
- 20+ Special Checks/Year

Ultrasonic Detection
- Acoustic Vibration Monitoring / Condition Based Lubrication
- Energy Conservation – Steam, Air, Nitrogen, Hydrogen
- 104 Machines Monitored

Mechanical Integrity
- Vessel Inspections
- Relief Device Testing & Inspection
- Piping / Vent Line Inspection - UT, X-Ray, Gamma Scans, Neutron Backscatter





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References

There are a lot of excellent articles on this subject, but this presentationutilized:

RCM II by John Moubray available from most bookstores (Strongly recommended)

Steve Turner with OMCS has a three part article on the Future of Maintenance. I especially like his thoughts on data collection. (PMO vs RCM is in part 2)
http://www.reliabilityweb.com/articles/pmo_stats01.htm
Choosing Maintenance analysis techniques Steve Turner OMCS www.ReliabilityAssurance.com
Six steps to condition-based maintenance PlantServices.com David Berger
Six Steps to a Healthy Machine *Jim Taylor of Machinery Management Solutions, Inc.*
"**Don't waste your time with condition monitoring" "Is there a stairway to asset heaven?"** www.lifetime-reliability.com

Questions?