Operation, Maintenance and Reliability of Geothermal Power Plant

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Training for Engineers on

Geothermal Power Plant

Yogyakarta, 9-13 October 2017

Reliability

Reliability is the conditional probability of a product or a toolswill work without failure (damage) according to its expected function at a specific duration and environments.

When we discuss about quantitative reliability, then its context was probability. Meanwhile, probability that represents reliability index values between 0 (zero) to 1 (one). Reliability of the system/component with index values 0 consideredhaving 0% chance of success and reliability index values 1 consideredhaving 100% chance of success. This reliability values is a time function, which means that reliabilityof a system/componentwill show various condition according to the time where the reliability evaluations performed. Similar system/component which measured at the similar operation time probably have different reliability if operating conditions of those similar systems/components are different.

Reliability

Probability is a value that indicates the ratio of the two numbers which is the amount of an incident divided by the total number ofincidents that can occur.Reliability is the probability from the number of missions that successfully runs divided by the total number of missions undertaken.

If the number of successful missions within the duration t is NS (t) and the total mission undertaken is NT (t), then reliability can be formulated as,

$$R(t) = \frac{NS(t)}{NT(t)}$$

If the number of successful missions written by the undertaken missions number reduced by the amount of failed missions NF (t), then the formula becomes:

$$R(t) = \frac{NT(t) - NF(t)}{NT(t)} = 1 - \frac{NF(t)}{NT(t)} = 1 - Q(t)$$

or

R(t) = 1 – unreliability

Basic probability theory will be discussed further in next chapter.

Availability Performance & Productivity

AVAILABILITY PERFORMANCE

The ability of equipment to function properly, Despite occurrence of failures, disturbances and Limitations in the maintenance resources.

Availability performance can be divided in to tree parts:

- ❑Reliability Performance
- ❑Maintenance Support Performance
- ❑Maintainability Performance

Reliability Performance

The ability of an item, under stated Conditions of use, to perform a required Function under stated conditions for a stated period of time.

Maintenance Support Performance

The ability of a maintenance organization, Under stated condition, to provide upon Demand the resources required to Maintain an equipment.

Maintainability Performance

The ability of an equipment, under started conditions of use, To be retained or restored to state in which it can perform a required function, when maintenance is performed under stated conditions and using stated procedure and resources.

Reliability Section

- Plant Status
- Capacity vs Period Hours
- Capacity Factor
- Equivalent Availability Factor
- Equivalent Forced Outage Rate

Plant Status

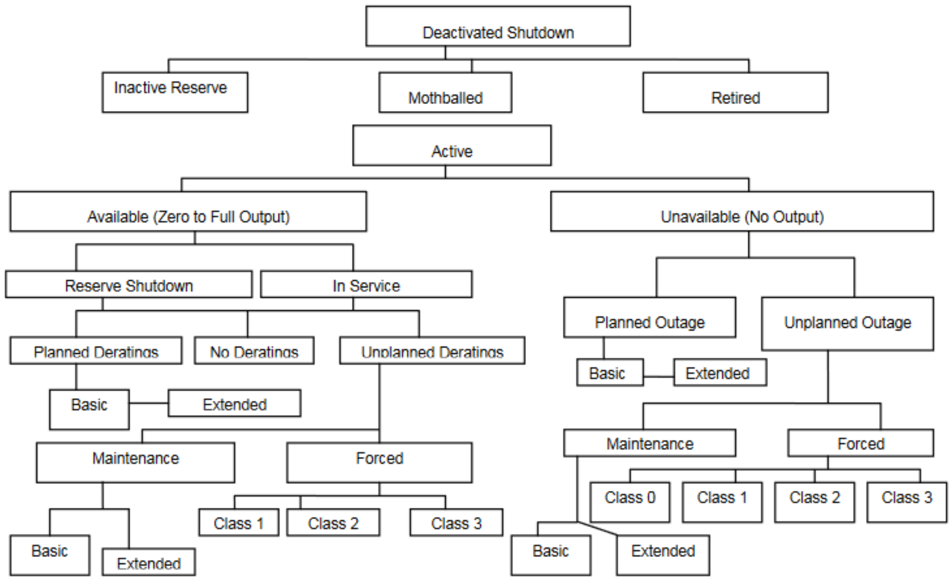


Figure 1—Relation between unit states

Capacity VS Period Hours

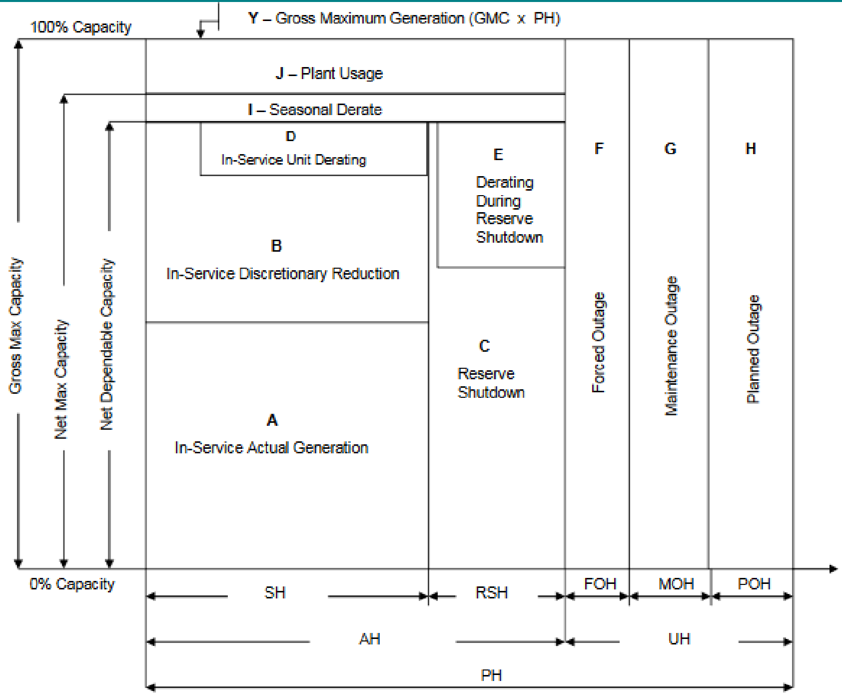


Figure C.1—Area for categories of capacity versus period hours

Capacity Factor

$$NCF = \left(\frac{NAAG}{NMG}\right) \times 100$$

The net energy that was produced by a generating unit in a given period (NAAG) as a fraction of the net maximum generation (NMG). NMG is the period hours (PH) times the net maximum capacity (NMC)

Equivalent Availability Factor

The EAF is the fraction of maximum generation that could be provided if limited only by outages and deratings:

$$EAF = \left(\frac{AG}{MG}\right) \times 100$$

$$EAF = \left(\frac{AH - (EUNDH + ESDH)}{PH}\right) \times 100$$

Equivalent Forced Outage Rate

A measure of the probability that a generating unit will not be available due to forced outages or forced deratings.

$$EFOR = \left(\frac{FOH + EFDH}{SH + FOH + ERSFDH} \right) \times 100$$

Maintenance

Maintenance is defined as the work of keeping an operating system in good condition or putting it in working order again after it fails. Maintenance refers to the collection of activities that include inspections, overhauls, repairs, preservation of parts and replacements carried on an operating equipment to preserve its functions, avoid consequences of failure and ensure its productive capacity.

Maintenance of engineering systems is responsible for keeping the equipment healthy, safe to operate and suitably configured to perform their tasks efficiently. Maintenance functions in production plants have major impacts on product delivery, product quality and production cost.

History of Maintenance

Maintenance, which began in the 1930s can be divided into three generations that have characteristics as follows:

- **The first generation (before1950)**

- Repairs carried out when the damage occurred.

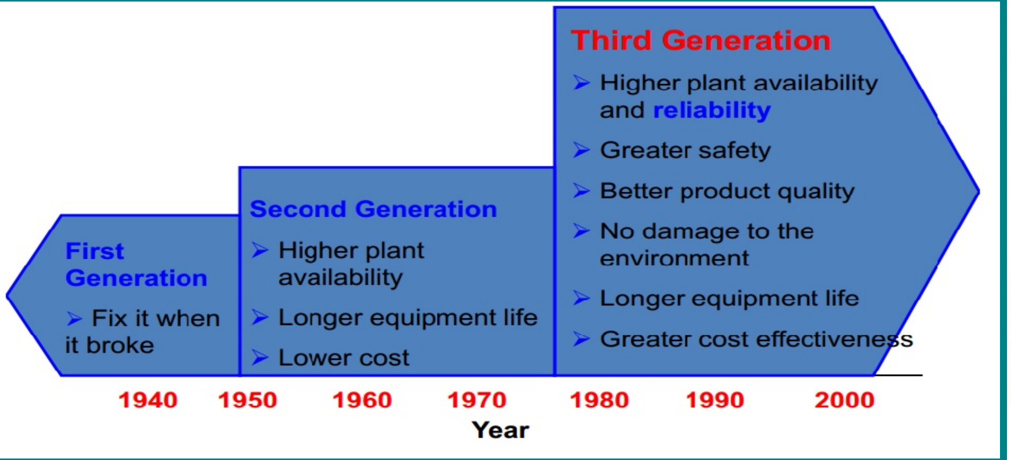
- **The second generation (1950 to 1970)**

- Higher plant availability
- Longer equipment life
- Lower maintenance costs

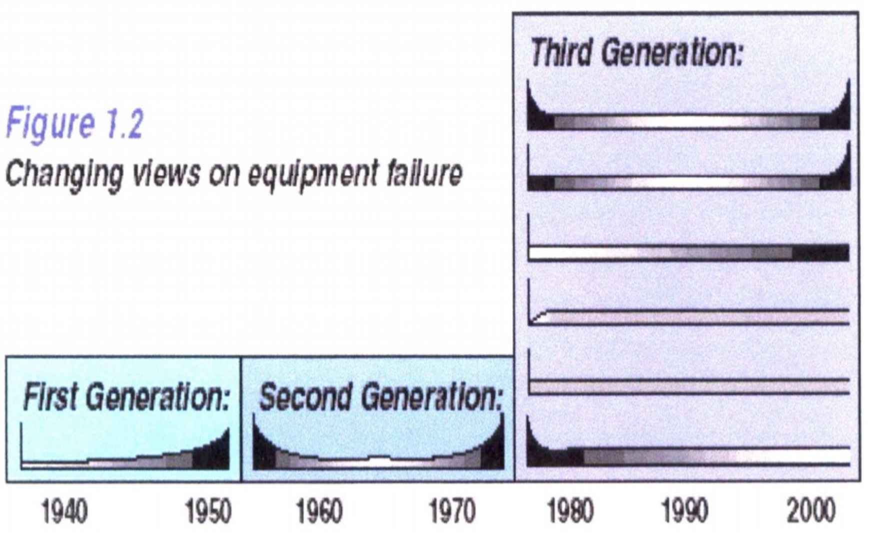
- **The third generation (late 1970 to now)**

- Higher plant availability and reliability
- Security is much better
- Better product quality
- No damage to the environment
- A longer life of the equipment
- The cost of care more effective

History of Maintenance



Schematic Diagram of Maintenance History



Schematic Diagram of Failure History

Purpose, Why must do Maintenance??

PLANT

MAINTENANCE

- Maximising Production
- Minimising Energy Usage
- Optimising Useful Life of Equipment
- Providing Budgetary Control
- Optimising Resources Utilisation

- Reduce Breakdowns
- Reduce Downtime
- Improving Equipment Efficiency
- Improving Inventory Control
- Implementing Cost Reduction

FAILURES

Random Failures

Non-Predictable

Regular Failures

Predictable

Failure Developing time(FDT)

Some failures either they are random or regular, have longer or shorter failure development time. The failure development time is the deterioration time from the moment condition departs from the normal condition until the moment of break down occurs.

Failures with failure development time is easier to handle than the failures without failure development time.

- Shorter FDT – Continuous on line condition monitoring has to be applied

- Longer FDT – Off-line condition monitoring has to be applied

FAILURE PATTERNS

There are six forms of failure and the illustration is shown in Figure.

A. Failure Shape

Constant or slightly increasing the level of the possibility of failure, then "WEAR OUT". Compatible with mechanical equipment such as pumps, valve and piping (erosion).

B. Failure Shape

Also known as the "bathtub curve", starting with the high failure incidence rates (known as "infant mortality"). Continued with a constant failure rate, then "WEAR OUT". Complex mechanical devices that were damaged prematurely, such as gearboxes, transmissions etc.

C. Failure Shape.

The possibility of failure increases slowly, but is not identified "WEAR OUT". Fatigue in structures.

FAILURE PATTERNS

D. Failure Shape

There is an increased chance of failure when the equipment is new or just out of the shop, then increased rapidly until at a constant level. Fatigue or creep on the structure.

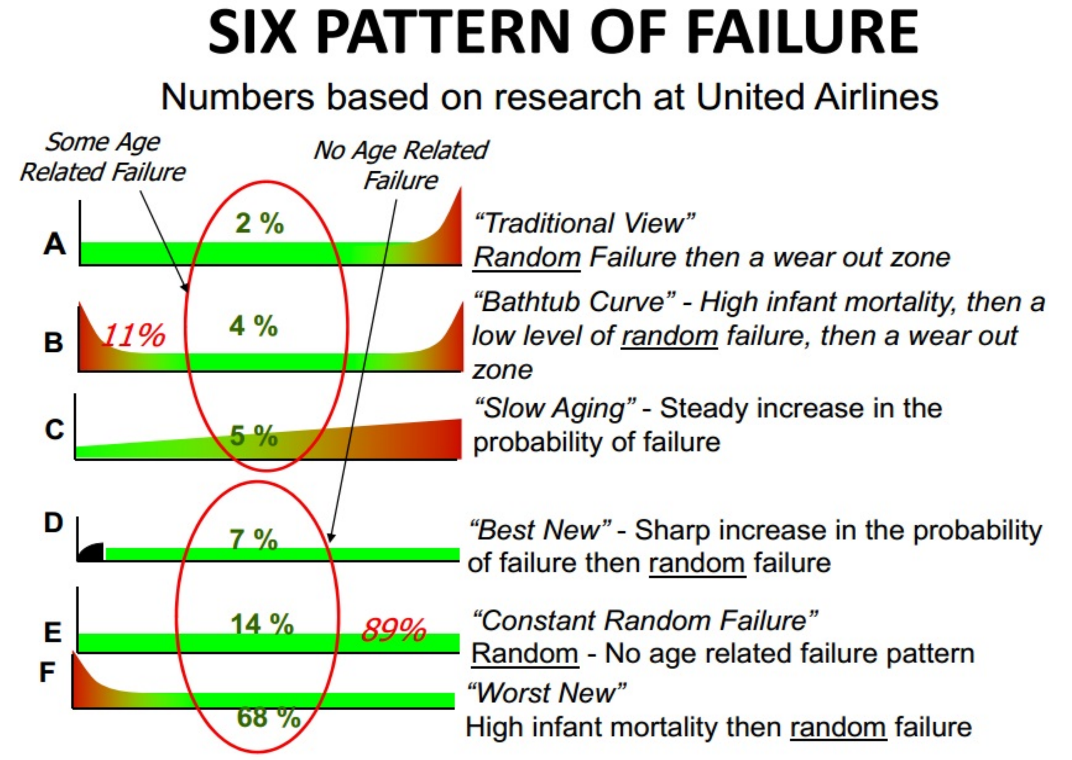
E. Failure Shape

The level of probability of failure is relatively constant during operation. Electro-mechanical complex in the absence of a dominant failure mode. Or equipment are experiencing enormous loading.

F. Failure Shape

Starting with the possibility of failure incidence rate is quite high (infant mortality), then down to the condition of a constant or increased very low. Electronic components and PLC.

Pattern of Failure



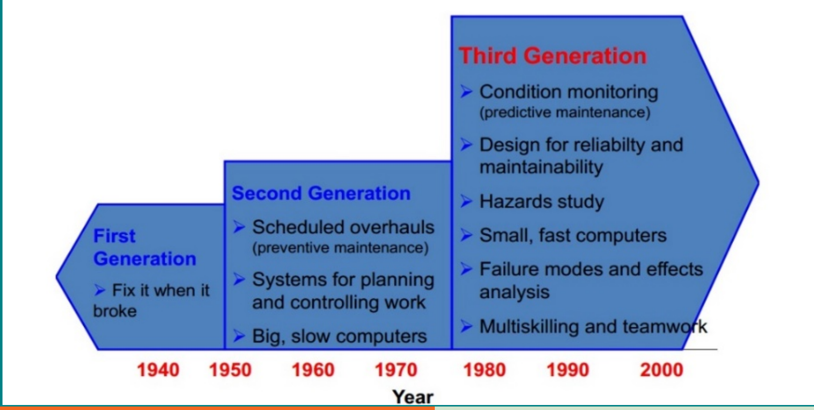
Six Failure Pattern

A. Failure Shape
B. Failure Shape
C. Failure Shape.
D. Failure Shape
E. Failure Shape
F. Failure Shape

History of Mechanical Maintenance

Mechanical maintenance has evolved as much as three generations is illustrated in Fig. 4.

- The first generation (before 1950)
  - Repairs carried out when the damage occurred.
- The second generation (1950 to 1970)
  - Scheduled maintenance (preventive maintenance)
  - The system for planning and controlling work
  - Using a large computer and slow
- The third generation (late 1970 to now)
  - Monitor the condition of the tool (predictive maintenance)
  - It is designed for reliability and ease of maintenance
  - The study of occupational hazards
  - Using small and fast computer
  - Using FMEA (Failure Modes and Effects Analysis)
  - Multitasking and is based on teamwork



Different type of Maintenance

- Maintenance
  - Planned Maintenance
    - Preventive Maintenance
      - Running maintenance
      - Shutdown maintenance
      - Scheduled maintenance
    - Corrective Maintenance
      - Breakdown maintenance
      - Shutdown maintenance
    - Predictive Maintenance
  - Unplanned maintenance
    - Emergence maintenance

Type of Maintenance

- Breakdown Maintenance

  It means that people waits until equipment fails and repair it. Such a thing could be used when the equipment failure does not significantly affect the operation or production or generate any significant loss other than repair cost.

- Preventive Maintenance

  It is a daily maintenance (cleaning, inspection, oiling and re-tightening), design to retain the healthy condition of equipment and prevent failure through the prevention of deterioration, periodic inspection or equipment condition diagnosis, to measure deterioration. It is further divided into periodic maintenance and predictive maintenance. Just like human life is extended by preventive medicine, the equipment service life can be prolonged by doing preventive maintenance.

- Predictive Maintenance

  This is a method in which the service life of important part is predicted based on inspection or diagnosis, in order to use the parts to the limit of their service life. Compared to periodic maintenance, predictive maintenance is condition based maintenance. It manages trend values, by measuring and analysing data about deterioration.

Type of Maintenance

- Corrective Maintenance

It improves equipment and its components so that preventive maintenance can be carried out reliably. Equipment with design weakness must be redesigned to improve reliability or improving maintainability

- Condition Based Maintenance

Condition monitoring is the process of determining the condition of machinery while in operation.

The key to a successful condition monitoring programme includes:

1. Knowing what to listen for,
2. How to interpret it
3. When to put this knowledge to use

Condition monitoring not only helps plant personnel reduce the possibility of catastrophic failure, but also allows them to order parts in advance, schedule manpower, and plan other repairs during the downtime.

Breakdown Maintenance

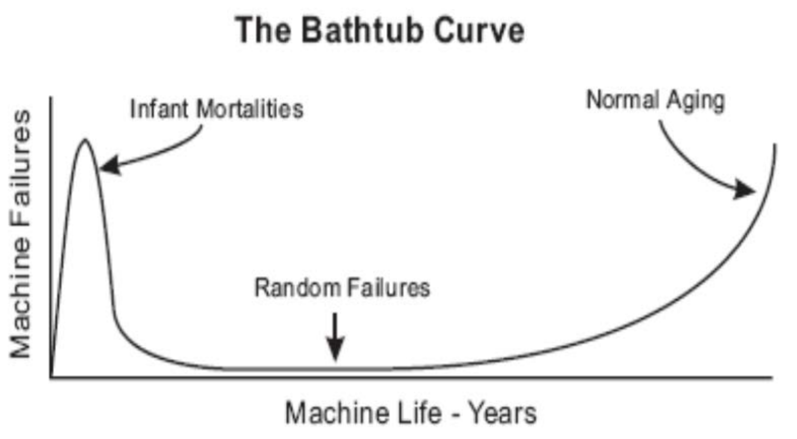
- It is an emergency based policy in which the plant or equipment is operated until it fails and then it is brought back into running condition by repair.
- The maintenance staff locate any mechanical, electrical or any other fault to correct it immediately.
- It is feasible for the small factories where
  1. There are few types of equipment.
  2. Machine and equipments are simple and does not require any specialist.
  3. Where sudden failure does not cause any serious financial loss.

Breakdown Maintenance

Advantages	Disadvantages
Lower start up cost	Unpredictability
Limited personnel requirement	Equipment not maximised
Reduced maintenance costs	Indirect costs
Potentially increased margins	

Preventive Maintenance

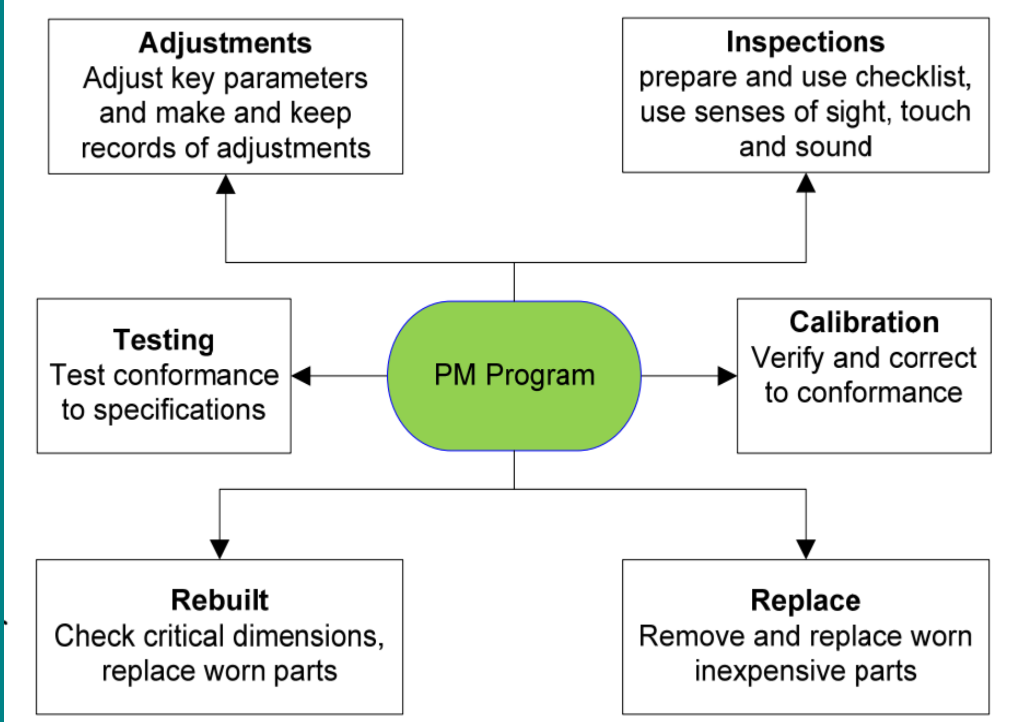
Preventive maintenance (PM) is a time based maintenance method in which the maintenance activities are planned and scheduled based on predetermined counter intervals in order to prevent breakdowns and failures from occurring.The primary goal of PM is to preserve and enhance equipment performance and reliability by preventing failure of equipment before it failure occurs by such actions as replacing worn components. PM is commonly used where equipment failure is age related or where the equipment failure rates follow what is called bath-tub curve (as Figure).



Preventive Maintenance Procedures

The requirements for a good PM procedure include the following:

- A list of tools, spare parts and instruments required.
- A form to record the measurements to be made.
- Limits or ranges for the parameters to be measured.
- Required safety procedures such as isolation and locking out



Preventive Maintenance

Advantages	Disadvantages
Over all very cost effective	Catastrophic failure still a risk
Flexibility can allow for adjustment of schedule to accommodate other work	Labour Intensive
Increased equipment life	Performance of maintenance based on schedule not required
Saved energy cost resulting from equipment running from pick efficiency	Risk of damage when conducting unneeded maintenance
Reduced equipment or process failure	Saving not readily visible without a base line
Over all saving between 12% to 18%	

Predictive Maintenance

As the names implies it involves the prediction of the failure before it occurs, identifying the root cause for those failures symptoms and eliminating those causes before they result in extensive damage of the equipment.

Type of maintenance performed continuously or at intervals according to the requirements to diagnose and monitor a condition or system. Also called condition based maintenance.

Example of Predictive Maintenance

- Vibration Analysis
- Infrared Thermography
- Oil Analysis
- Visual Inspections

Predictive Maintenance

Advantages	Disadvantages
Increased component operational life/availability	Increased investment of diagnostic equipment
Allows for pre-emptive corrective action	Increased staff training for analysing data
Decreased part and labour cost	Saving not readily visible without a baseline/history
Improved safety and environment	
Energy savings	
Over all saving between 8% to 12% over preventive maintenance	

Corrective Maintenance

CORRECTIVE MAINTERANCE

UNPLANNED

- ❖Break Down
- ❖Emergency Repairs
- ❖Urgent
- ❖Not possible to Control
- ❖You are controlled by the equipment

PLANNED

- ❖Planned Maintenance
- ❖Prepared Properly
- ❖Possible to Control
- ❖You control the Equipment

Corrective Maintenance

According to reliability solutions (Plucknette, 2002), the run to failure strategy is suitable in conditions where:

- Failure cannot be predicted through the use of condition monitoring such as where failure occurs too quickly to be predicted.
- Failure cannot be prevented by using a PM task.
- Failure cannot be eliminated through redesign such as where the component has been in service several years with no failures and there is no justification for redesign.
- Failure has no or limited consequences on safety and production and the cost from failure are low.

Corrective Maintenance

Corrective maintenance (CM) is the maintenance strategy in which equipment is allowed to run until it fails after which maintenance is scheduled and executed.

Important do in CM:

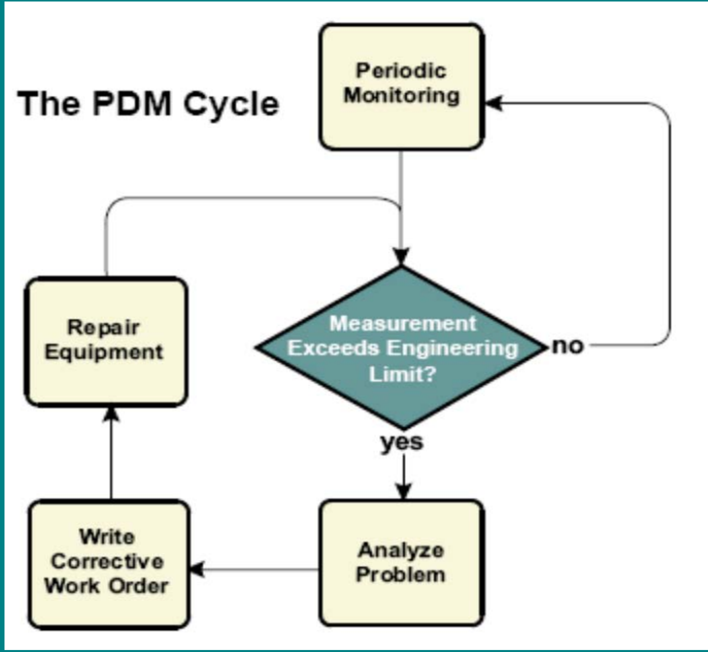
- Use original OEM parts
- Install per manufacturer's specs
- Don't take shortcuts
- Do it right

Advantages	Disadvantages
Lower short-term costs	Increased long-term costs due to unplanned equipment downtime.
Requires less staff since less work is being done	Possible secondary equipment or process damage.
	Prone to neglect of assets

Condition Based Maintenance

Condition based maintenance (CBM) is a set of maintenance actions based on the evidence of need for maintenance obtained from real time assessment of equipment condition, obtained from embedded sensors and external tests and measurement taken by portable equipment. CBM is a technology that strives to identify incipient faults before they become critical which enables accurate planning of PMs. PdM is part of CBM practices because the maintenance actions are related to measured parameters.

The main objectives of CBM or predictive maintenance (PdM) is to improve system reliability and availability, product quality, security, best programming of maintenance actions, reduction of direct maintenance costs, reduction of energy consumption and meeting standards. CBM is suitable where the cost of failure is high and if the cost of installing a CBM system is economical.



Condition Based Maintenance Technique and Applications

No	CBM procedure	Applications
1	Vibration analysis	Misalignment, out of balance weights, wear of bearings etc
2	Thermography analysis	Overloading, excessive friction or wear, abnormal electric resistance
3	Ultrasonic analysis	Steam leakage, corona discharge, excessive friction or wear, lubrication breakdown
4	Oil analysis	Contamination, breakdown of lubrication properties, signs of wear
5	Current measurement	Electric overloads, faulty bearings, current leakage
6	Laser alignment tests	Misalignment of rotating shafts, checking level of surfaces
7	Visual inspection	General defects that can be detected by human senses of sight, hearing and feeling
8	Insulation tests	Check status of electric insulation
9	Power rate	Bearing failures, damaged turbine blades, vacuum loss
10	Voltage measurement	Brush failure, excitation faulty, insulation failure

Condition Based Maintenance

Advantages	Disadvantages
Extend bearing service life	Monitoring equipment costs
Maximise machine productivity	Operational costs (running the program)
Minimise unscheduled downtime	Skilled personnel needed
Safely extend overhaul intervals	Strong management commitment needed.
Improve repair time	A significant run-in time to collect machine histories and trends is usually needed.
Increased machine life	
Improve product quality	
Reduce product cost	
Enhance product safety	

Impact of Poor Maintenance

- Production Capacity
- Production Costs
- Product and Service Quality
- Employee or Customer Safety
- Customer Satisfaction

Proper Maintenance Planning

Results in the correct maintenance work is carried out

- ❑ At the right time
- ❑ In the right way
- ❑ By the right professional
- ❑ With the right spare parts

“Real maintenance management is impossible without condition based preventive maintenance”

Maintenance Procedures

When a maintenance strategy is going to be formulated, there are many maintenance procedures that could be chosen, From sophisticated procedures to low level procedures.

- Operate to break down (unplanned corrective maintenance), O.T.B.D
- Fixed-time maintenance, F.T.M
- Condition-based maintenance, C.B.M
- Design out maintenance, D.O.M
- Life-time extension, L.T.E
- Redundancy, RED

Total Productivity Maintenance

- TPM is a way of organizing maintenance to support productivity & quality through increased equipment efficiency and to reduce costs.
- TPM concept means that all employees work in small groups to maximize the improvement of equipment efficiency.
- Operators are working independently with all maintenance activities of their own equipment and have also the total responsibility of operation and maintenance.

Fundamental Goals of TPM

- ✓Increased productivity and quality
- ✓Zero defects
- ✓Reduced cost of maintenance and production
- ✓Increased motivation among all employees
- ✓Zero accident
- ✓Shorter lead time
- ✓Zero unplanned stops
- ✓Development of staff through training
- ✓Improvement of work environment

Incentives for MMS or CMMS (rule of thumb)

Reduction on MDT	about 20%
Increased machine life	about 20 %
Saving on labour and spares	10 – 20%
Savings on maintenance budget	10 – 20%

Maintenance Management Systems

General of maintenance systems

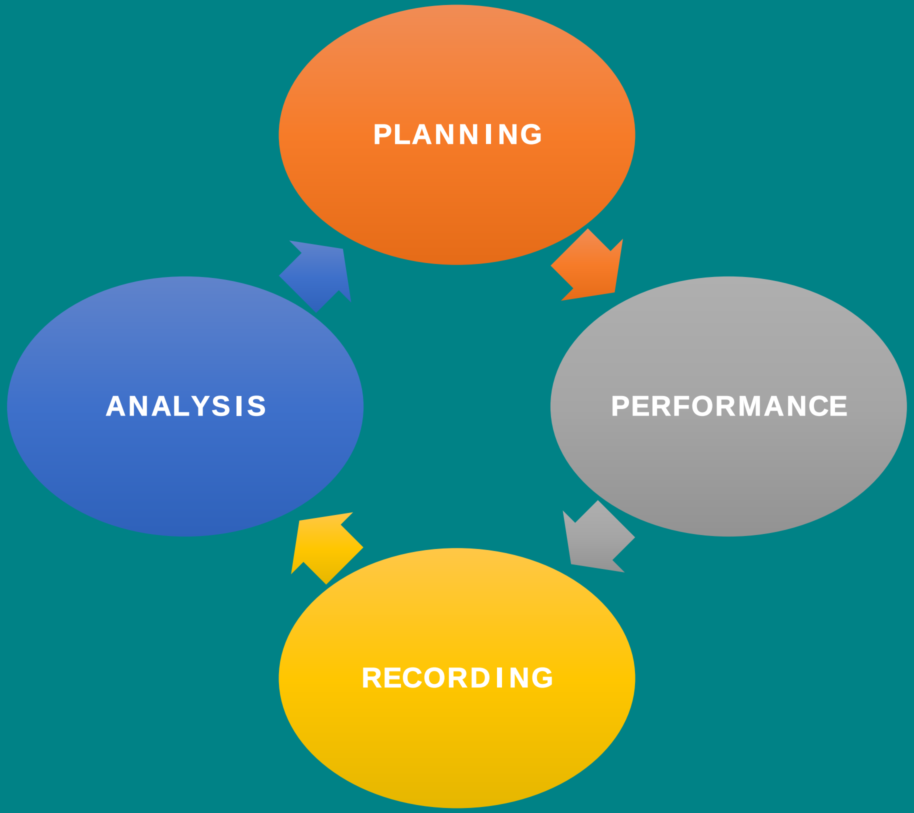
The maintenance function must also have necessary aids to manage the maintenance activities to coop up to the main target of the enterprise. Maintenance management means a better control of the maintenance organization and the related area. To properly control the maintenance of a facility, information is required to analyze what is occurring.

To be able to manage the maintenance activities in the right way, a maintenance management system is necessary. The system can be either manual or computerized. The main purpose of a maintenance management system is in operation and works properly.

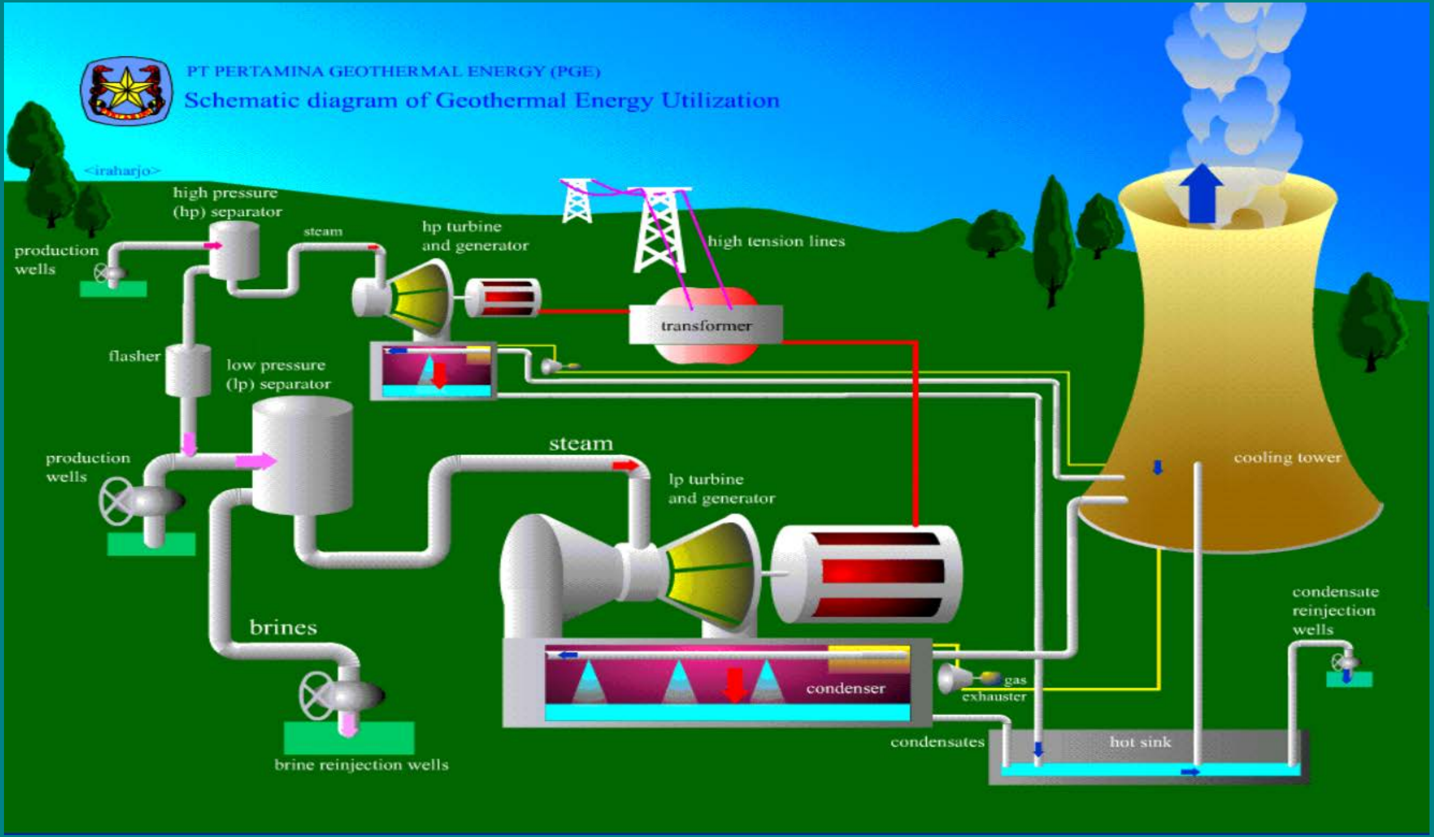
The basic function of a maintenance management system can be :

1. Preventive maintenance
2. Plant and unit record(Equipment)
3. Inventory and spare parts control system, Purchasing system
4. Document record
5. Planning system for maintenance and work order routines
6. Technical/economic analysis of plant history, maintenance and machine availability

The Basic Maintenance Cycle



Geothermal Power Plant



Maintenance in Geothermal Power Plant

Operating a geothermal power plant is a continous process where equipment has to be maintained on a regular basis to keep the facility capable of providing the expected output. Most problems encountered in the production are related to the chemical composition of the geothermal fluid. Geothermal power plants can be divided into gathering system, turbine and cold ends. Within the gathering system are wells, wellheads and separators. About 5-6 production wells are usually needed for a 30MW single-flash power plant. The only moving part of a wellhead is the gate segment in valves and they are vulnerable against scaling, which builds up and can always be found there.

Maintenance in Geothermal Power Plant

A drop in pressure or temperature increases the amount of scaling and any leak in the wellhead or pipelines will immediately cause scaling. Corrosion also affects the wellheads, and the worst type can be found on the outside of the wellhead. Both the amount of scaling and corrosion depend on the composition of the working fluid.

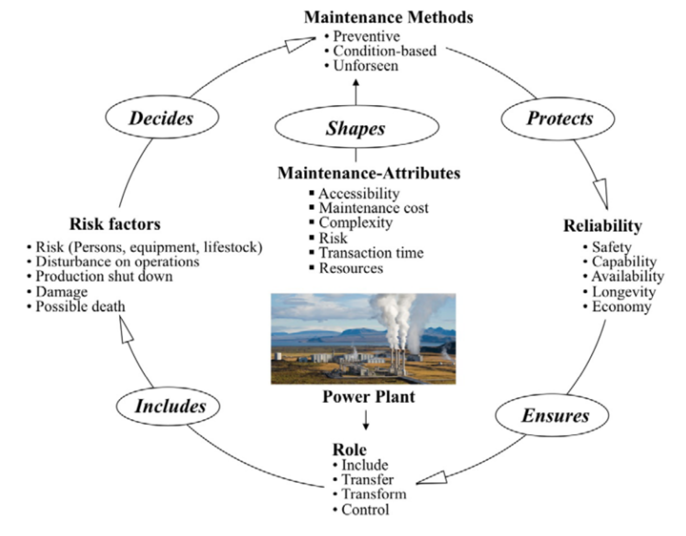
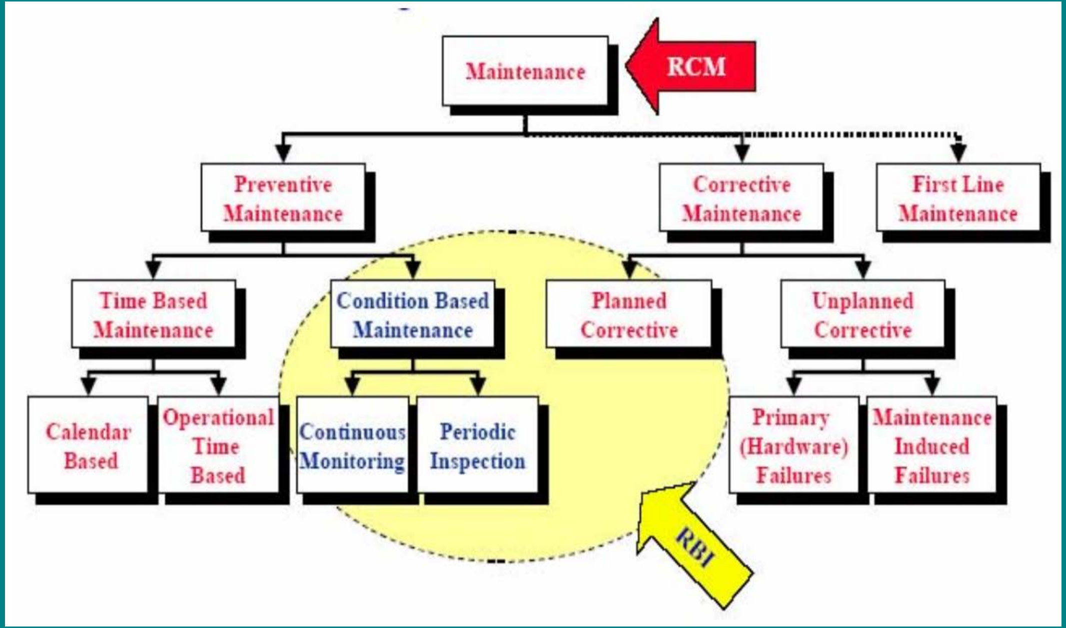


Figure 3 Interconnections of critical factors in maintenance [33].

Maintenance Structure-Reliability Centered Maintenane



RCM is one of the best known and most used devices to preserve the operational efficiency of the steam system. RCM operates by balancing the high corrective maintenance costs with the cost of programmed (preventive or predictive) polices, taking into account the potential shortening of "useful life" of the item considered. But it is difficult to select suitable maintenance strategy for each piece of equipment and each failure mode, for the great quantity of equipment and uncertain factors of maintenance strategy decision [3,4].

About RCM:

Reliability centred maintenance (RCM) is an analytical method used to determine appropriate failure management strategies to ensure safe and cost-effective operations of a physical asset in a given operating environment. The RCM approach requires an extensive knowledge of the reliability and maintainability of the system and its components. The important elements in RCM are the mean time between failure (MTBF), mean time to repair (MTTR) and failure rate (FR). Some guiding questions used in RCM development include:

- What are the functions and associated performance standards of the asset in its present operating context?
- In what ways does the asset 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 prevent each failure?
- What should be done if a suitable preventive task cannot be found?

Key Objective RCM Method

No.	Main objectives	How they are achieved
1	Ensure equipment reliability	Reliability modelling
2	Ensure safety through appropriate PM actions	Classify types of failure Analyze failure consequences
3	Ensure equipment functionality in the most economic manner	Effectiveness of PM Economic viability of PM Preservation of function

Summary of the key objectives of an RCM method (IDCON Inc., 2006)

RCM is very useful method when designing, selecting, and installing new systems in a plant, setting up preventive maintenance for complex equipment and systems whose functioning is not clearly understood and when teaching people the basics of reliability. RCM is not be very useful when defining PM procedures for typical plant equipment like pumps, motors, couplings, cylinders and hydraulics since their failure modes are well known and tedious RCM procedure cannot be justified. RCM is suitable for newly installed equipment and complex systems where failure modes are not clear but their reliability and safety requirements are high.

Required Materials and Documentation of RCM

– The system or process description (operations manuals)

– Plant, Piping and Instrument Drawings

– Schematic Drawings of electrical and I&C systems

– Plant and equipment list for mechanical, electrical and I&C

– Lists of Preventive Maintenance and Technical Specification Testing and Inspection
programmes.

– Plant vendor drawings and manuals

– Plant maintenance history (including corrective maintenance)

– Regulatory and insurance obligations, operating instructions, alarm response procedures
and operator records.

– PSA analysis for the system where that is available

RCM as Tool for Optimization of Operation and Maintenance

RCM is a decision making tool. Operations and maintenance programmes can benefit both the processes involved in the decision-making, “soft“ benefits and the outcomes, that result in the changes to maintenance and operations programmes. examples:

- The act of performing the RCM decision-making process provides a benefit in promoting better co-operation among all of those involved in the process.
- The process demands that all established tasks are challenged with the objective of justifying continued use or removing/replacing them with other tasks, in doing so it promotes a healthy questioning attitude.
- The process raises awareness of the functions of the systems involved, the consequences of failure of those functions and the economics of operating and maintaining them.

The clear aims of RCM are to improve reliability and optimise the cost effectiveness of maintenance activities. When performed effectively it will result in the elimination of unnecessary maintenance tasks and the introduction of measures to address omissions and deficiencies in maintenance programmes.

The Principles of RCM

The RCM analysis process centres on the functions of plant and equipment, the consequences
of failure and measures to prevent or cope with functional failure. The process must establish
answers to the following questions and an effective response to them:-

– What are the functions and performance standards of the plant?
– In what ways 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?

Component of RCM Program

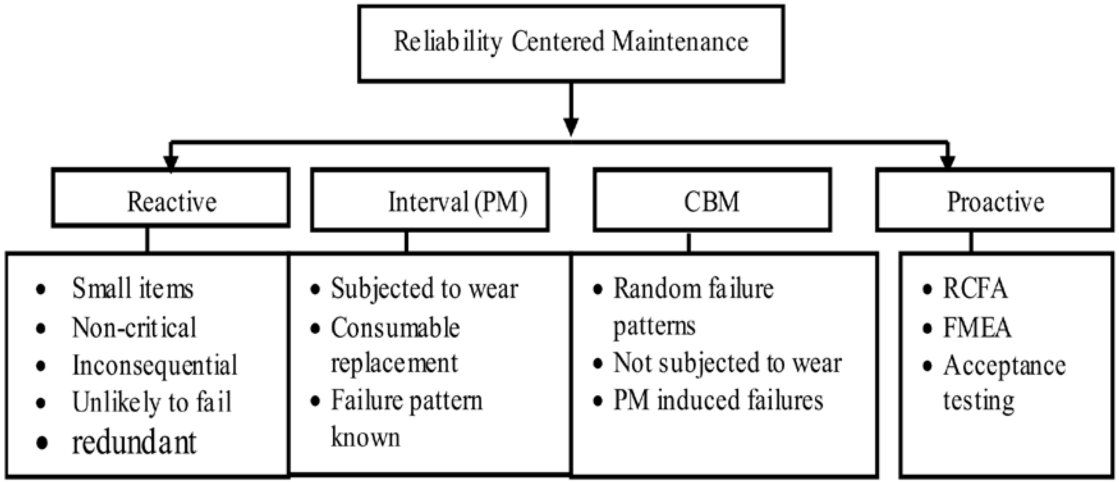


Figure 1. Components of RCM program.

The components of RCM program are shown in Figure. This figure showing that RCM program consists of (reactive maintenance, preventive maintenance, condition based maintenance, and proactive maintenance) and its patterns.

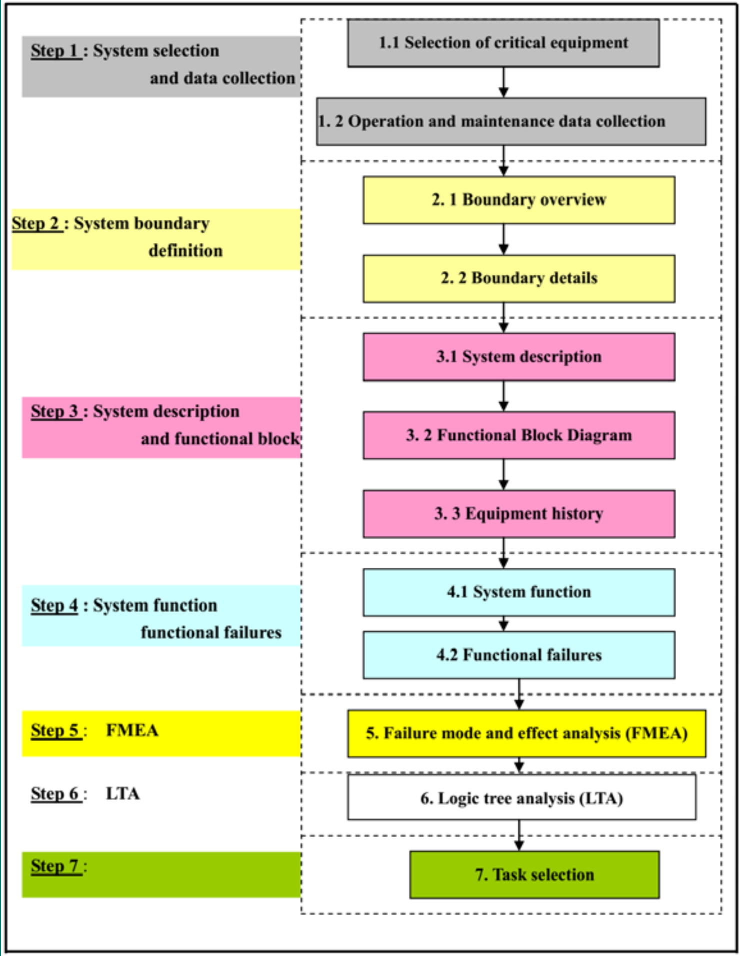


Figure 2. Main steps of the RCM.

Step of RCM technique

As shown in **Figure**, the RCM steps are presented. The steps describe the systematic approach used to implement the preserves the system function, identifies failure mode, priorities failure used to implement the preserves the system function, identifies failure mode, priorities failure modes and performs PM tasks. The RCM steps are:

- Step1: system selection and data collection.
- Step2: system boundary definition.
- Step3: system description and functional block.
- Step4: system function functional failures.
- Step5 : failure mode effect analysis
- Step6: logic tree diagram.
- Step7: task selection

1. System Selection and Data Collection

Determining the list of the system components is one of the first steps in RCM. The criticality analysis requires different kind of data of each component that build up the system. The effect of failure of the system main components may effect system productivity and maintenance cost. The factors effecting selection of critical system are as follows:

1. Mean-time between failures (MTBF).
2. Total maintenance cost.
3. Mean time to repair (MTTR).
4. Availability.

2. Logic Tree Analysis (LTA)

The basic (LTA) uses the decision tree structure shown in **Figure 3**. From this figure, decision bins: 1) safetyrelated, 2) outage-related, or 3) economic-related were noticed. Each failure mode is entered into the top box of the tree, where the first question is posed: Does the operator, in the normal course of his or her duties, know that something of an abnormal or detrimental nature has occurred in the plant? It is not necessary that the operator know exactly what is awry for the answer to be yes [6].

3. Criticality Analysis

Criticality analysis is a tool used to evaluate how equipment failures impact organizational performance in order to systematically rank plant assets for the purpose of work prioritization, material classification, PM/PdM development and reliability improvement initiatives [9]. In general, failure modes, effects and criticality analysis (FMEA/FMECA) requires the identification of the following basic information in **Table**. In **Figure**, algorithm for the calculation of equipments criticality is presented. This figure shows the calculation steps of the equipments criticality The criticality is assessed based on the effect of errors/faults and on the time from the occurrence until the effect occurs on the installation and is quantified with 1, 2, 3 in **Table 1.**

$$EC = (30*P + 30*S + 25*A + 15*V)/3 \quad (1)$$

where,

EC: is the equipment criticality, %

P: is the product

S: is the safety

A: is the equipment stand by

V: is the capital cost.

Factors for consideration in RCM implementation

- RCM benefits are often derived over a medium to long term period therefore, plant personnel should not expect to experience gains in cost or performance right away. Such expectations should be discouraged.
- The use of contractors in the RCM process is often an expedient way of making progress when no experience of the process exists in an organisation. RCM however it should form part of the normal business process. Over the longer term it is important to develop in house capability to avoid dependence on contractors.
- The RCM process will involve both significant changes to the work practices and the inter relationships between the maintenance practitioners and the operators. These changes will prove to be beneficial but as with all change management programmes they will require the engagement of the participants for them to succeed. Measures must be taken to secure that engagement, failure to do will result in costly delays.
- Think hard about which RCM methodology will best meet your objectives. Classical RCM can be extremely demanding in the form of time and resources. Whereas streamlined versions of RCM can deliver many of the benefits without the level of resource commitment required with classical RCM.

Benefits

- ✓Operations and maintenance personnel work together during this exercise
- ✓Maintenance is aligned with the objectives of the production process
- ✓The maintenance tasks and programs are justified on a formal basis
- ✓The quality of the experience feedback data is improved (those who collect them use them).
- ✓A culture of economic performance is developed in the maintenance personnel.
- ✓A sustainable process is implemented for continuous re-questioning of the validity of the maintenance decision
- ✓Non-intrusive maintenance is enhanced.
- ✓Corporate monitoring of the maintenance function and networking between stations are reinforced on the occasion of the implementation of the process of definition, validation, updating of maintenance program supervised by corporate experts. Even if the cause-effect link cannot be directly showed,
- ✓effects contribute to the reduction of maintenance costs.

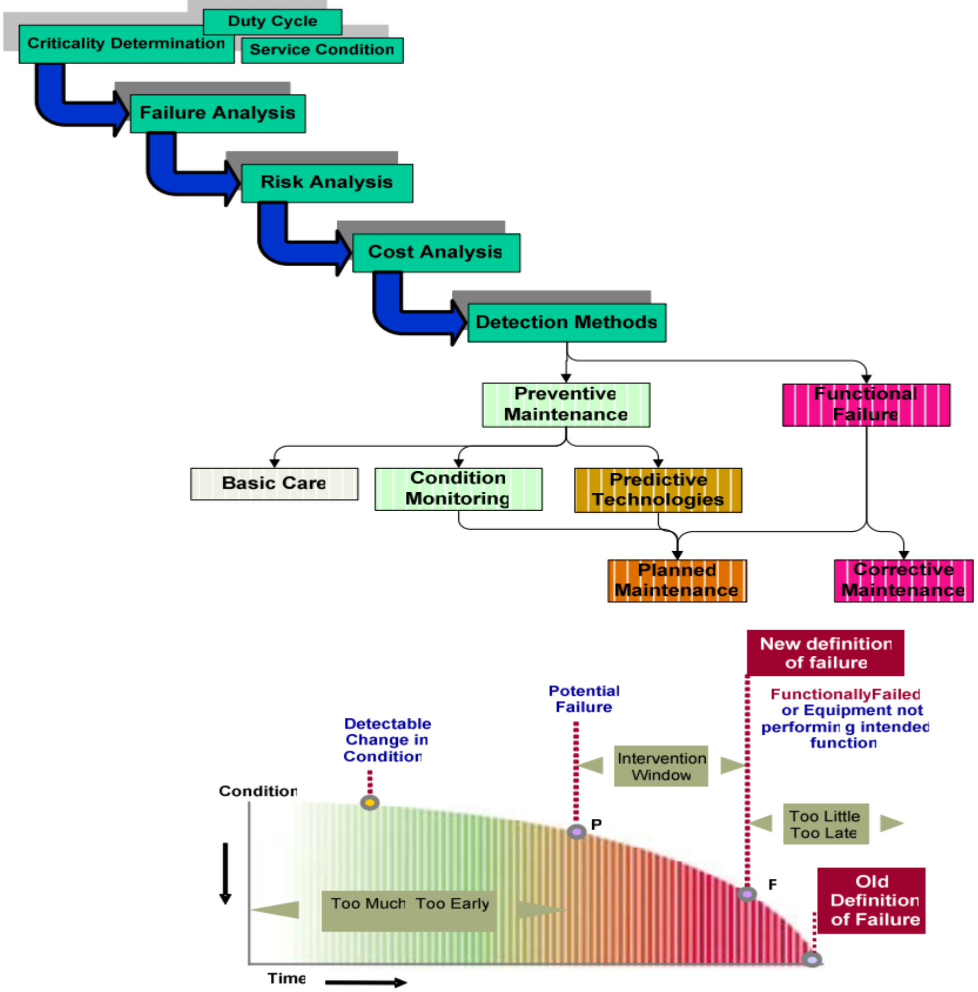
Benefits - Reliability

The overall aim of the RCM process is not necessarily to reduce the cost of the maintenance programmes but to improve the functional performance of the plant equipment. Enhanced reliability and efficiency will in turn contribute to improved economic and safety performance of the plant equipment.

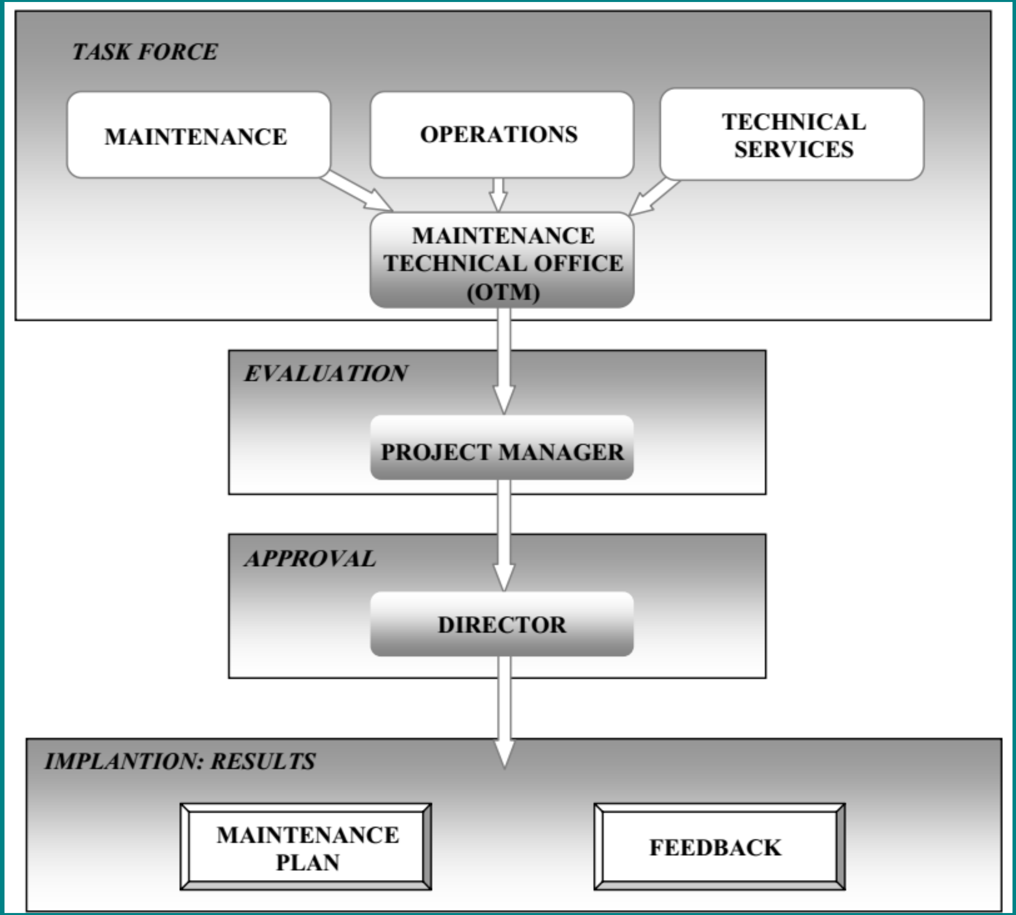
Benefits - Contribution to Long Term Operation

RCM is a systematic approach to the identification and execution of maintenance activities designed to support plant performance. The associated condition monitoring programmes and analytical techniques ensure excellent knowledge of plant condition and can provide early warning of plant aging and obsolescence issues which are vital for asset management. The data collected and the maintenance practices developed are conducive to long term asset management strategies.

Streamlined RCM. Doing the Right Work, at the Right Time, Based on Equipment Condition.

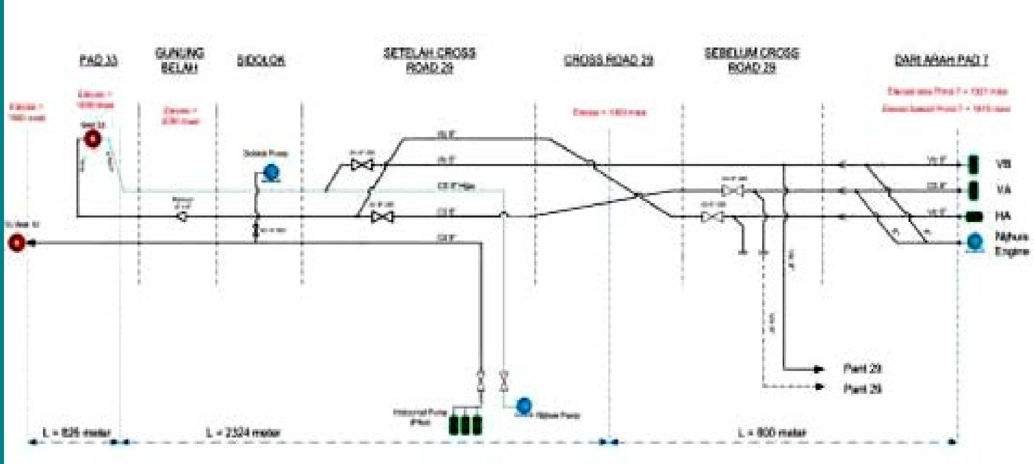


Implementation of RCM in company



Case Study

Development of northern cold brine injection system is mean to accommodate brine which production from separation process of well production at PAD 7 and PAD 29. In the PAD 7 use three pump consist of one horizontal pump(deep blue) and two vertical pump (VA and VB). While at PAD 29 use three horizontal pump consist of SC, DB-1, and DB-2. Configuration of piping line from each brine injection system which originated from PAD 7 and PAD 29 can be viewed from Fig.27 and Fig.28.



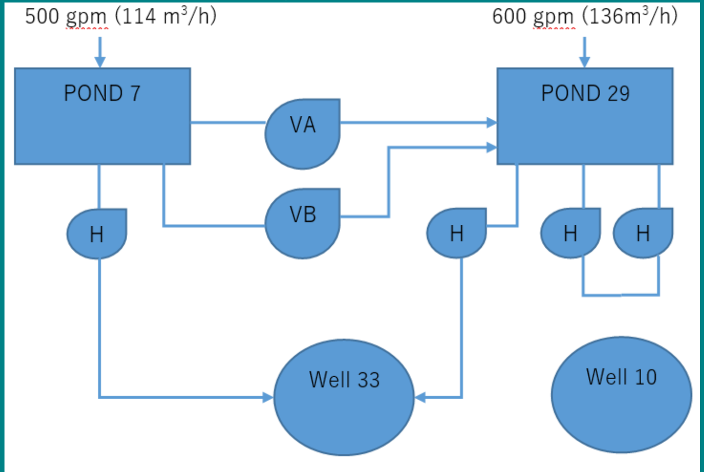


Fig.28 Configuration of Cold Brine Injection System

Data of production well

Main Component:

- Canal System
- Pond di PAD 7 and PAD 29
- Pump
- Piping
- Power Line
- Main Physic Boundary

Start from:

- Brine to the canal
- Electricity to the pump

End with:

- Brine enter to injection well
- Silica sludge dredged and is c

Table 3 Production Well

Well Name	Load Assumptions (MW)	WHP (psi.g)	Brine (gpm)
HCE-7B	3	450	200
HCE-7C	15	455	650
HCE-29	3	407	150
HCE-29A	4	661	200

Table 4 Data of Pond

Pond Name	Capacity (m^3)
Pond PAD 7	5400
Pond PAD 29	8200

Table 5 Boundary Overview

Type	Bounding System	Interface Location	Reference
In	Hot Brine	Brine from Silencer enter to pond via canal	P&ID
In	AC Power Supply	Electric Motor	P&ID
Out	Cold Brine	Cold Brine enter to injection well via piping	P&ID
Out	Silica Scaling	Silica Sludge dredged via canal	P&ID

Description

Canal:

Trench serves to drain the brine out of Silencer heading to the pond. In the trenches temperature decreases will lead to silica easier to settle so expect a silica content as brine enter the pond is already much lower.

Pond:

Pond serves to accommodate provisional brine that will be injected into the injection wells. At the pond is also expected silica deposition process so that the amount of silica that is flowing through the pipe leading to the injection wells have been even lower. Capacity pond at PAD 7 is 5200 m^3, while the capacity of PAD pond at 29 is 8400 m^3.

Description

Pump:

Pump function provides the necessary head to overcome the head of the piping system so that the target can be achieved the desired discharge.

Piping:

Piping line of northern brine injection system cover of,

Pond 7 – Reinjection well 33

1. Pond 29 – Reinjection well 33
2. Pond 29 – Reinjection well 10
3. Pump VA – Canal 29
4. Pump VB – Canal 29

Power Line:

Electricity networkwhich used from the PLN with 380 Volt of voltage, 3 phase and 50 Hz of Frequency.

Asset Block Diagram

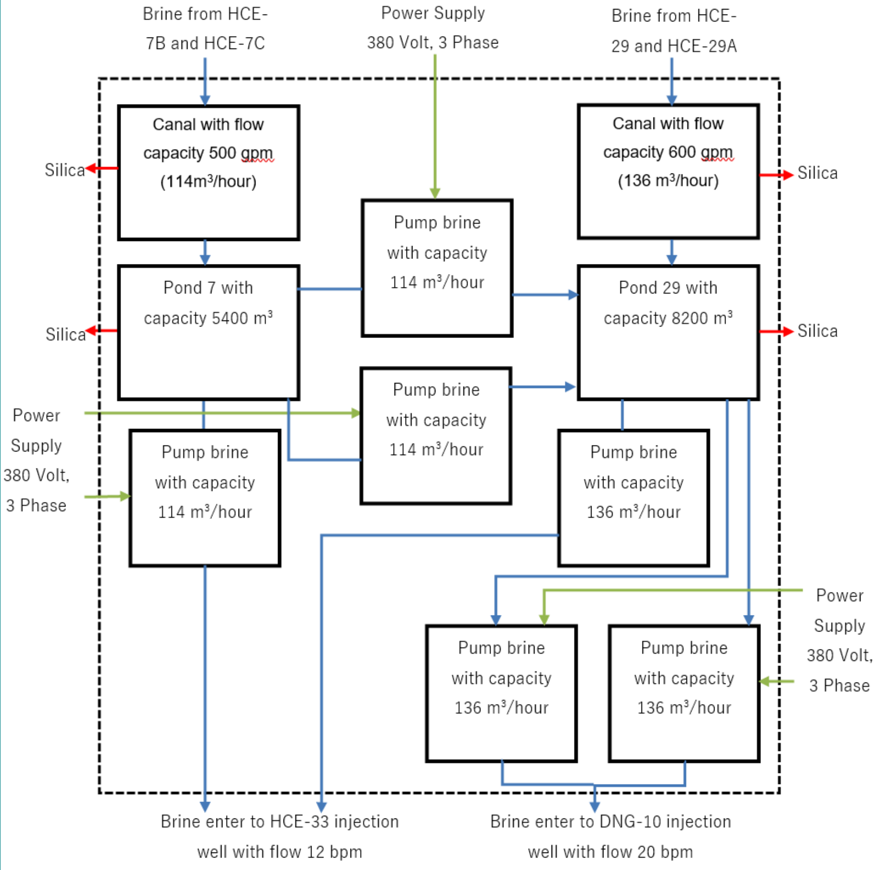


Fig.30 ABD Brine Injection System

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