Class Objectives

By the end of the class, the students are expected to know the following:

- **Maintenance History**

  The progression of maintenance over different stages of histories

- **Maintenance Types**

  Types of maintenance that are currently used, fields of applications, advantages and disadvantages of each type.

Maintenance Definition

British Standard Glossary of terms (3811:1993) defined maintenance as:

> the combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function.

Maintenance Definition

maintenance is a set of organised activities that are carried out in order to keep an item in its best operational condition with minimum cost acquired.

Maintenance Activities

Activities of maintenance function could be either repair or replacement activities, which are necessary for an item to reach its acceptable productivity condition and these activities, should be carried out with a minimum possible cost.

Maintenance History

- In the period of **pre-World War II**, people thought of maintenance as an added cost to the plant which did not increase the value of finished production.

- Therefore, the maintenance at that era was restricted to fixing the unit when it breaks because it was the cheapest alternative.

Maintenance History

- During and ***after World War II*** at the time when the advances of engineering and scientific technology developed, people developed other types of maintenance, which were much cheaper such as preventive maintenance.

- In addition, people in this era classified maintenance as a function of the production system.

Maintenance History

- **Nowadays**, increased awareness of such issues as environment safety, quality of product and services makes maintenance one of the most important functions that contribute to the success of the industry.

- World-class companies are in continuous need of a very well organised maintenance programme to compete world-wide

Maintenance History

Maintenance History

Maintenance Types

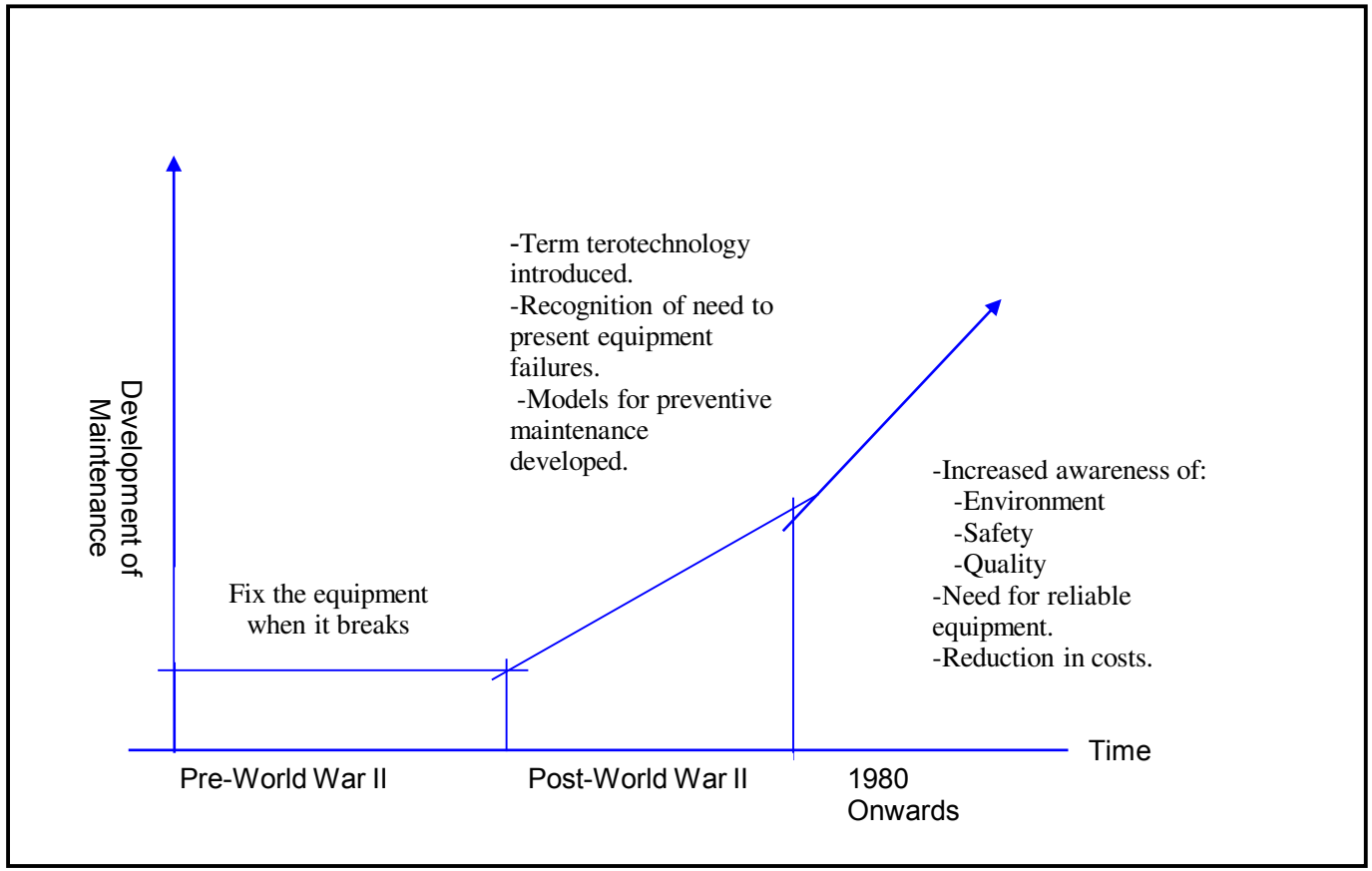


Figure 2.2 Maintenance History
(Adapted From Shenoy, Bhadury 1998)

Maintenance Objectives

- Maintenance objectives should be consistent with and subordinate to production goals.

- The relation between maintenance objectives and production goals is reflected in the action of keeping production machines and facilities in the best possible condition.

Maintenance Objectives

- Maximising production or increasing facilities availability at the lowest cost and at the highest quality and safety standards.
- Reducing breakdowns and emergency shutdowns.
- Optimising resources utilisation.
- Reducing downtime.
- Improving spares stock control.

Maintenance Objectives

- Improving equipment efficiency and reducing scrap rate.
- Minimising energy usage.
- Optimising the useful life of equipment.
- Providing reliable cost and budgetary control.
- Identifying and implementing cost reductions.

Maintenance Objectives

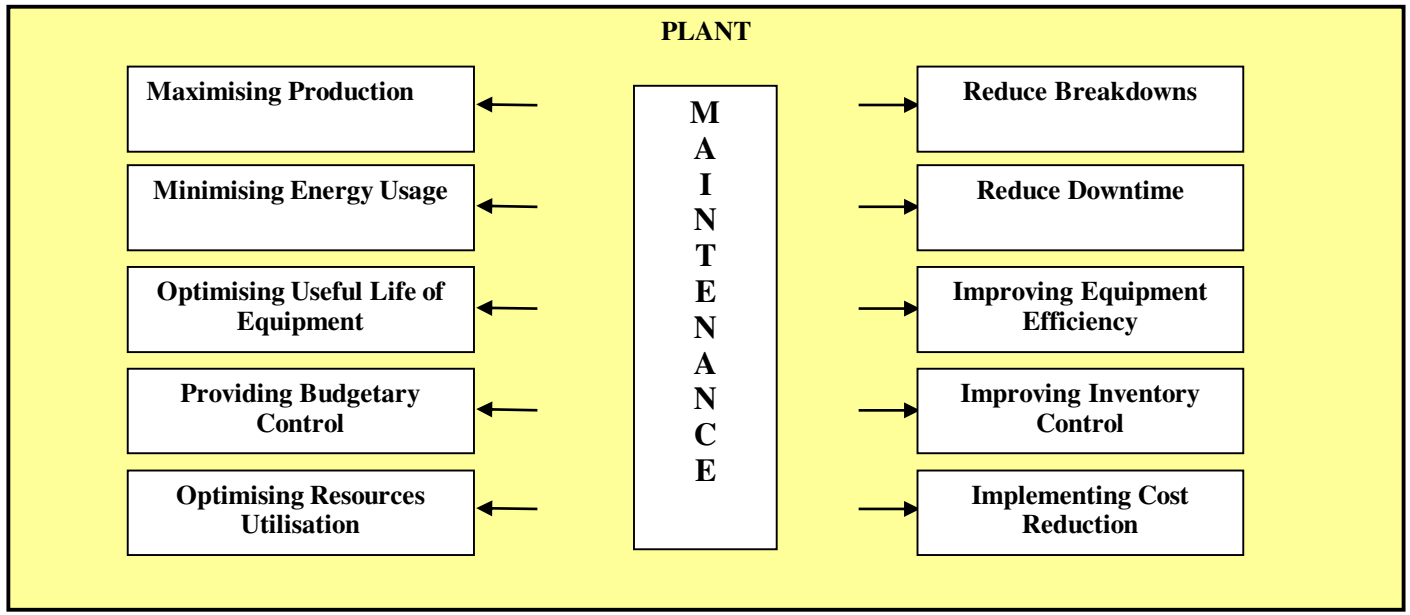


Figure 2.3 Maintenance Objectives

Maintenance Types

- Run to Failure Maintenance (RTF)
- Preventive Maintenance (PM)
- Corrective Maintenance (CM)
- Improvement Maintenance (IM)
- Predictive Maintenance (PDM)

Maintenance Types

Run to Failure Maintenance (RTF)

- The required repair, replacement, or restore action performed on a machine or a facility after the occurrence of a failure in order to bring this machine or facility to at least its minimum acceptable condition.
- It is the oldest type of maintenance and it is subdivided into two types:
  - Emergency maintenance: it is carried out as fast as possible in order to bring a failed machine or facility to a safe and operationally efficient condition.
  - Breakdown maintenance: it is performed after the occurrence of an advanced considered failure for which advanced provision has been made in the form of repair method, spares, materials, labour and equipment.

Maintenance Types

RTF Disadvantages

- Its activities are expensive in terms of both direct and indirect cost.
- Using this type of maintenance, the occurrence of a failure in a component can cause failures in other components in the same equipment, which leads to low production availability.
- Its activities are very difficult to plan and schedule in advance.

RTF Advantages

- The failure of a component in a system is unpredictable.
- The cost of performing run to failure maintenance activities is lower than performing other activities of other types of maintenance.
- The equipment failure priority is too low in order to include the activities of preventing it within the planned maintenance budget.

Maintenance Types

Preventive Maintenance (PM)

- It is a set of activities that are performed on plant equipment, machinery, and systems before the occurrence of a failure in order to protect them and to prevent or eliminate any degradation in their operating conditions.
- The maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning and the effects limited (British Standard 3811:1993)
- It is good for those machines and facilities which their failure would cause serious production losses.
- Its aim is to maintain machines and facilities in such a condition that breakdowns and emergency repairs are minimised.
- Its activities include replacements, adjustments, major overhauls, inspections and lubrications.

Maintenance Types

Factors Affecting Preventive Maintenance

- The need for an adequate number of staff in the maintenance department in order to perform this type of maintenance.
- The right choice of production equipment and machinery that is suitable for the working environment and that can tolerate the workload of this environment.
- The required staff qualifications and skills, which can be gained through training.
- The support and commitment from executive management to the PM programme.
- The proper planning and scheduling of PM programme.
- The ability to properly apply the PM programme

Maintenance Types

Preventive Maintenance (PM)

Researchers subdivided preventive maintenance into different kinds according to the nature of its activities:

- **Routine Maintenance** which includes those maintenance activities that are repetitive and periodic in nature such as lubrication, cleaning, and small adjustment.
- **Running Maintenance** which includes those maintenance activities that are carried out while the machine or equipment is running and they represent those activities that are performed before the actual preventive maintenance activities take place.
- **Opportunity Maintenance** which is a set of maintenance activities that are performed on a machine or a facility when an unplanned opportunity exists during the period of performing planned maintenance activities to other machines or facilities.

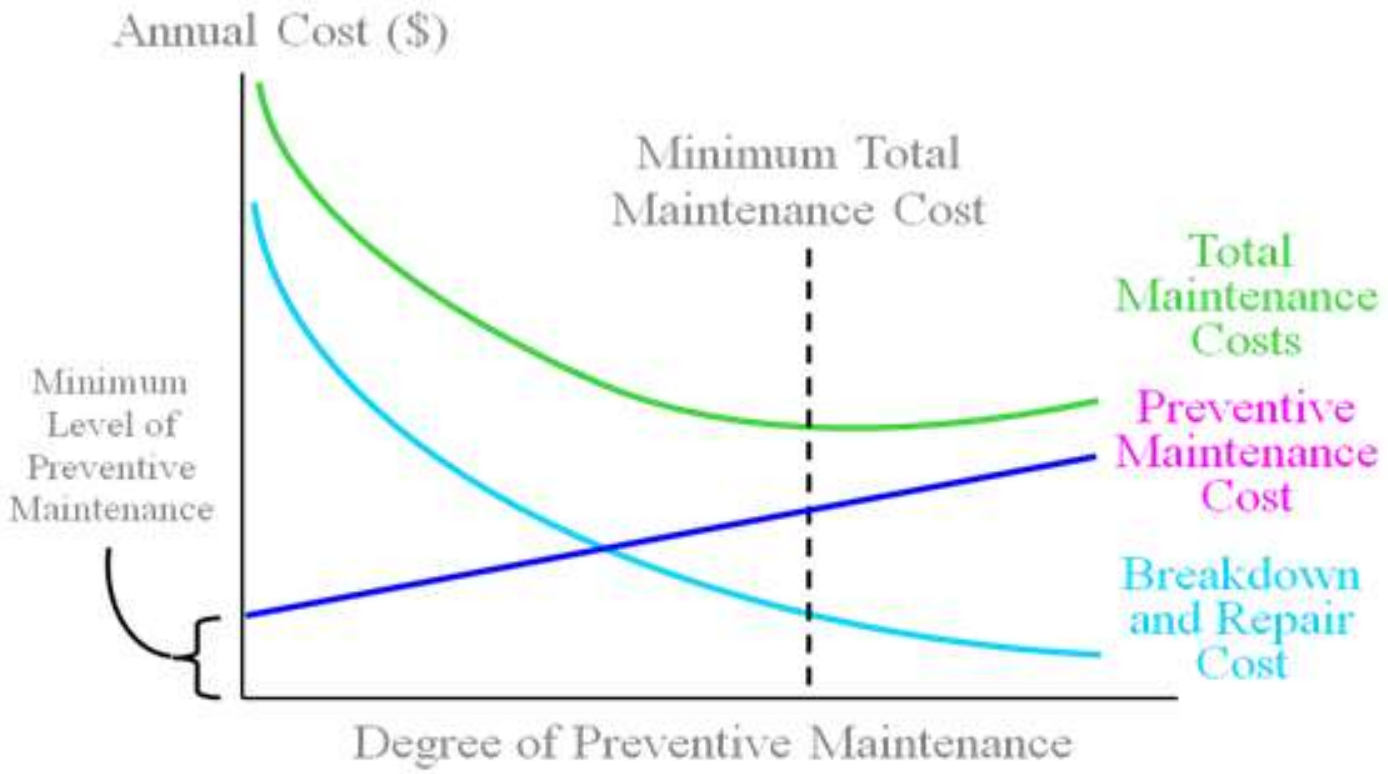
Maintenance Types

- **Window Maintenance** which is a set of activities that are carried out when a machine or equipment is not required for a definite period of time.

- **Shutdown Preventive Maintenance,** which is a set of preventive maintenance activities that are carried out when the production line is in total stoppage situation.

Maintenance Types

Maintenance Types



Maintenance Types

Corrective Maintenance (CM)

- In this type, actions such as repair, replacement, or restore will be carried out after the occurrence of a failure in order to eliminate the source of this failure or reduce the frequency of its occurrence.

- The maintenance carried out after recognition and intended to put an item into a state in which it can perform a required function (British Standard 3811:1993)

Maintenance Types

Corrective Maintenance (CM)

Corrective maintenance is subdivided into three types:

- **Remedial Maintenance**, which is a set of activities that are performed to eliminate the source of failure without interrupting the continuity of the production process.
  - The way to carry out this type of corrective maintenance is by taking the item to be corrected out of the production line and replacing it with reconditioned item or transferring its workload to its redundancy.
- **Deferred Maintenance**, which is a set of corrective maintenance activities that are not immediately initiated after the occurrence of a failure but are delayed in such a way that will not affect the production process.
- **Shutdown Corrective Maintenance**, which is a set of corrective maintenance activities that are performed when the production line is in total stoppage situation.

Maintenance Types

Advantaged and Disadvantages of Corrective Maintenance (CM)

- The main objectives of corrective maintenance are the maximisation of the effectiveness of all critical plant systems, the elimination of breakdowns, the elimination of unnecessary repair, and the reduction of the deviations from optimum operating conditions.
- The difference between corrective maintenance and preventive maintenance is that for the corrective maintenance, the failure should occur before any corrective action is taken.
- Corrective maintenance is different from run to failure maintenance in that its activities are planned and regularly taken out to keep plant's machines and equipment in optimum operating condition

Maintenance Types

- The way to perform corrective maintenance activities is by conducting four important steps:

1. Fault detection.
2. Fault isolation.
3. Fault elimination.
4. Verification of fault elimination.

In the fault elimination step several actions could be taken such as adjusting, aligning, calibrating, reworking, removing, replacing or renovation

Maintenance Types

Improvement Maintenance (IM)

- It aims at reducing or eliminating entirely the need for maintenance.
- This type of maintenance is subdivided into three types as follows:

1. **Design-out Maintenance** which is a set of activities that are used to eliminate the cause of maintenance, simplify maintenance tasks, or raise machine performance from the maintenance point of view by redesigning those machines and facilities which are vulnerable to frequent occurrence of failure and their long term repair or replacement cost is very expensive.
2. **Engineering Services** which includes construction and construction modification, removal and installation, and rearrangement of facilities.
3. **Shutdown Improvement Maintenance**, which is a set of improvement maintenance activities that are performed while the production line is in a complete stoppage situation.

Maintenance Types

Predictive Maintenance (PDM)

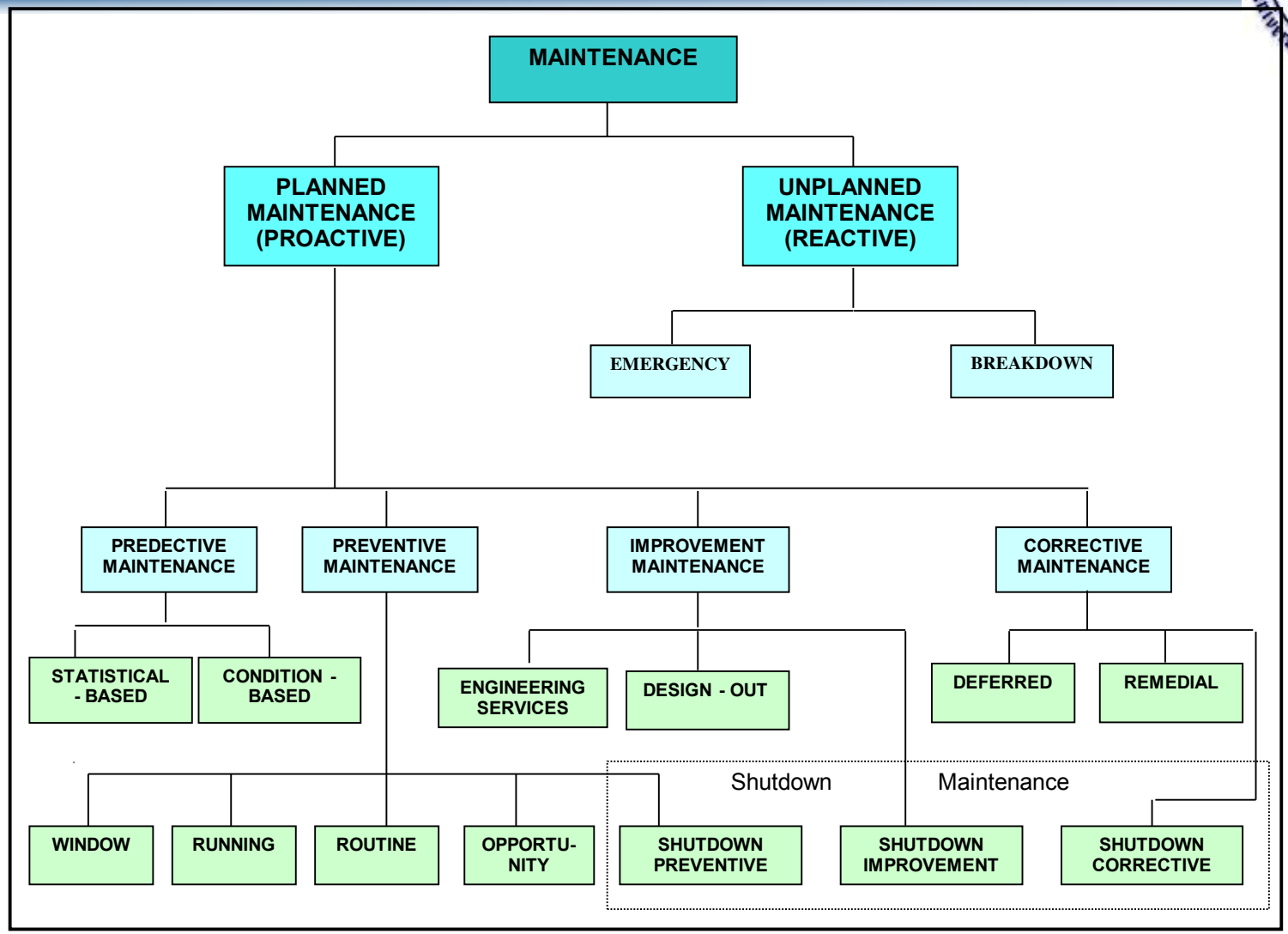
- Predictive maintenance is a set of activities that detect changes in the physical condition of equipment (signs of failure) in order to carry out the appropriate maintenance work for maximising the service life of equipment without increasing the risk of failure.
- It is classified into two kinds according to the methods of detecting the signs of failure:
  - Condition-based predictive maintenance
  - Statistical-based predictive maintenance
- **Condition-based Predictive Maintenance** depends on continuous or periodic condition monitoring equipment to detect the signs of failure.
- **Statistical-based Predictive Maintenance** depends on statistical data from the meticulous recording of the stoppages of the in-plant items and components in order to develop models for predicting failures

Maintenance Types

- The drawback of predictive maintenance is that it depends heavily on information and the correct interpretation of the information.
- Some researchers classified predictive maintenance as a type of preventive maintenance.
- The main difference between preventive maintenance and predictive maintenance is that predictive maintenance uses monitoring the condition of machines or equipment to determine the actual mean time to failure whereas preventive maintenance depends on industrial average life statistics.

Maintenance Types

Maintenance Types



Diagnostic Technologies

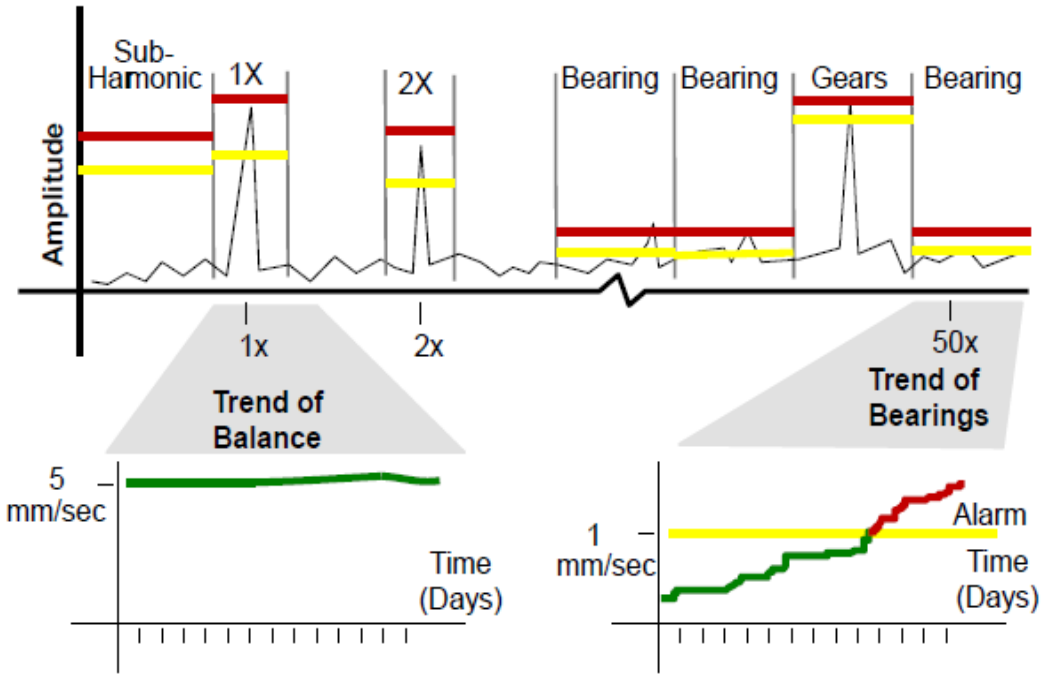
The most commonly applied condition-based maintenance techniques are Vibration Analysis, Oil Analysis, Thermography, Ultrasonic, Electrical Effects and Penetrates.

Vibration Analysis

- Vibration can be defined as the movement of a mass from its point of rest through all positions back to the point of rest, where it is ready to repeat the cycle. The time it takes to do this is its period, and the number of repetitions of this cycle in a given time is its frequency.
- The severity of vibration is determined by the amplitude - or maximum movement - its peak velocity and peak acceleration. Vibration analysis in condition monitoring, is accomplished by comparing vibration characteristics of current operation to a baseline, measured when the machinery was known to be operating normally. The selection of the specific parameters to be measured depends primarily on the frequency of the vibration.

Diagnostic Technologies

- Vibration analysis techniques can be used to monitor the performance of mechanical equipment that rotates, reciprocates or has other dynamic actions. Examples include gearboxes, roller bearings, motors, pumps, fans, turbines, belt or chain drives, compressors, generators, conveyors, reciprocating engines and indexing machines



Diagnostic Technologies

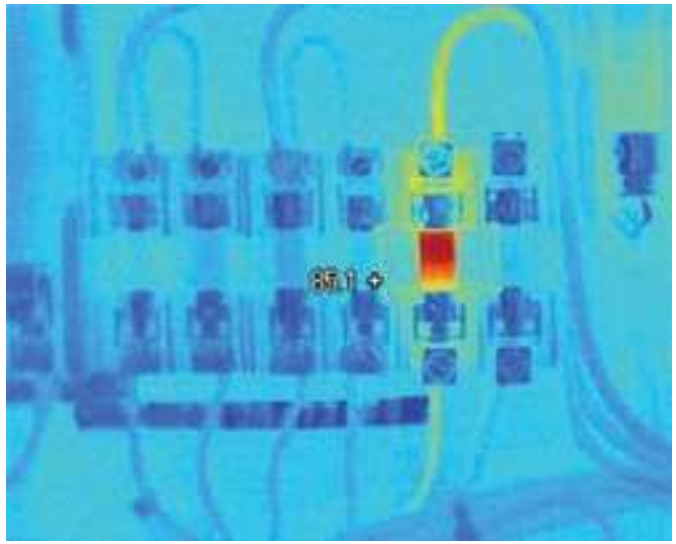
Oil Analysis

- Ferrography and magnetic chip detection examine the iron-based wear particles in lubrication oils to determine the type and extent of wear, and can help determine the specific component that is wearing
- Spectrometric oil analysis measures the presence and amounts of contaminants in the oil through atomic emission or absorption spectrometry
- It is useful for determining not only iron, but also other metallic and not metallic elements, which can be related to the composition of the various machine components, like bearings, bushings, piston rings, etc. It is useful when wear particles are initially being generated in the early stages of failure, as they are small.
- Chromatography measures the changes in lubricant properties, including viscosity, flash point, pH, water content and insoluble, through selective absorption and analysis.

Diagnostic Technologies

Thermography

- The most common uses for thermography, which measures the surface temperature through the measurement of infra-red radiation, are for determining poor electrical connections and hot spots, furnace and kiln refractory wear and critical boiler and turbine component overheating. An infra-red camera shows surface temperature variations, calibrated to provide the absolute temperature or temperature gradients through black and white or color variations.



Diagnostic Technologies

Ultrasonic

- There are several techniques for ultrasonic testing, but they all are used to determine faults or anomalies in welds, coatings, piping, tubes, structures, shafts, etc. Cracks, gaps, buildups, erosion, corrosion and inclusions are discovered by transmitting ultrasonic pulses or waves through the material and assessing the resultant signature to determine the location and severity of the discontinuity. This technique is also used to measure flow rates.

Diagnostic Technologies

Electrical Effects

- There are several tests for corrosion using a simple electric circuit monitored by varying degrees of sophisticated instrumentation. One technique is based on the electro-chemical polarization method in a vessel with corrosive liquid, it uses the electrical resistance across a probe inserted in the active environment.

- The most common for monitoring or testing motors or generators are voltage generators, including mergers. These measure the resistance of insulation, and apply a test voltage from 250 volts to 10,000 volts.

Diagnostic Technologies

Penetrants

- Electrostatic and liquid dye penetrants are used to detect cracks and discontinuities on surfaces, caused in manufacturing, by wear, fatigue, maintenance and overhaul procedures, corrosion or general weathering.

- The penetrant is applied and allowed to penetrate into the anomalies. The surface is cleaned and the penetrant revealed through direct visual, fluorescent or electrostatic techniques.

Diagnostic Technologies

AC Motor Example – Condition Based Maintenance

CBM Indication	Cause	Detection Parameters	Sensor
High Overall Vibration Level	[A] Improper Bedplate or Foundation Design or Construction [B] Defective or Improperly Installed/Maintained Motor Mounts [C] Misalignment with Driven Equipment	Vibration	Accelerometer
High Frame Temperature	[A] High Rotor Bearing Temperature [B] High Stator Winding Temperature [C] High Ambient Temperature	Temperature	RTD, Thermistor
High Rotor Bearing Temperature	[A] Over-greased [B] Under-greased [C] Excessive Bearing Wear	Temperature	RTD, Thermistor
Low/High Current at Motor	[A] Low/High Line Current [B] Motor Controller Failure	Current Reading	Current
Low Torque	[A] Low Voltage [B] Dropped Load	Torque/Voltage	Torque /Voltage
Phase Imbalance	[A] Line Voltage Imbalance	Phase Reading	Phase