Welding

Level-II

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Module Title: - Maintaining Welding Tools and Equipment

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Acronym

AMP	Effective Asset Maintenance Plan
CMMS	Computerized Maintenance Management System
EHS	Environmental Health And Safety
FMEA	Failure Mode And Effect Analysis
FTA	Fault Tree Analysis
LAP	Learning Activity Performance
MRO	Maintenance, Repair, And Overhaul
MTBF	Mean Time Between Failures
NLGI	National Lubricating Grease Institute
OEE	Overall Equipment Effectiveness
PHA	Permits, Preliminary Hazard Analysis
PM	Preventive Maintenance
PPE	Personal Protective Equipment
RCM	Reliability-Centered Management

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Introduction to the Module

In welding field; the maintaining welding tools and equipment projects helps to know how to Undertake programmed safety and maintenance checks, to perform Minor welding machine repair and preventive maintenance and to record maintenance history and store maintained tools or Equipment for welding field.

This module is designed to meet the industry requirement under the welding occupational standard, particularly for the unit of competency: **Maintaining Welding Tools And Equipment**.

This module covers the units:

- Programmed machine
- preventive maintenance
- tools and equipment

Learning Objective of the Module:-

- Undertake programmed safety and maintenance checks
- Perform preventive maintenance
- Record maintenance report and store tools /equipment

Module Instruction

For effective use this modules trainees are expected to follow the following module instruction:

1. Read the information written in each unit
2. Accomplish the Self-checks at the end of each unit
3. Perform Operation Sheets which were provided at the end of units
4. Do the "LAP test" giver at the end of each unit and
5. Read the identified reference book for Examples and exercise

Unit one: Program machine Maintenance

This unit is developed to provide you the necessary information regarding the following content coverage and topics:

- Inspection of **machines/equipment**
- Perform minor machine repairs
- Adjust machine moving parts
- Undertake removal/ replacement of consumable components
- Replace /topping up fluids and lubricants
- check on maintenance
- Undertake safety program and maintenance
- Record status report , report relationships and responsibilities

This unit will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Inspect Machines/equipment
- Perform Machine repairs
- Adjust machine moving parts to manufacturer's specifications
- Removal/ replacement of consumable components is undertaken
- Replace fluids and lubricants
- Checks are undertaken safely and to prescribed procedures.
- Status report is recorded on pro-forma and reported
- Identify team parameters, reporting relationships and responsibilities from team discussions

1. Program machine Maintenance

1.1. Inspection of machines/equipment

1.1.1. Introduction

General: Restoration of a broken, damaged, or failed device, equipment, part, or property to an acceptable operating or usable condition or state. See also beyond economic repair, major repair, normal repair, and reparability.

Repair means responding to the breakdown of equipment and undertaking work to correct the problem in order to return the equipment to a working condition.

Before equipment can be repaired, you need to be aware that there is a problem! Therefore, there should be a clearly understood system for reporting faults and breakdowns and equipment users should be encouraged to report faults and breakdowns as soon as possible. If there is no back-up equipment, a breakdown will mean that the service the equipment was providing will come to a halt.

Simple repairs can be done by the in-house or external maintenance and repair team. If the equipment is repaired where it is used, it is important that the team is trained to work safely and that they don't create hazards for patients or staff.

More complex repairs will be carried out by specialized maintenance personnel; they might come to the eye care unit or you may have to send the equipment to them for repairs.

In all these situations, it is important to keep equipment users informed of how long their equipment will be unavailable.

Some items of equipment will be found to be damaged beyond repair. For others, spare parts may no longer be available as the equipment has become outdated. These will have reached the end of their lives and must be taken out of service (decommissioned or retired) and be replaced if the service they provide is to continue. Equipment that is being decommissioned should be disposed of safely and according to proper disposal procedures. Remember to update your records accordingly.

1.1.2. Repair Shop

Whether you need the drive blade on your Power nail nailer replaced or a complete overhaul of your Hummel sander motor, Flooring insured, service center for all your flooring equipment repairs and maintenance. We are the only Bona Certified Machine Center, in our region as well as a certified warranty center for Pro Team and Clarke American as well as all the other major brands. Staffed by Industry trained and certified professionals, we are well equipped to diagnose and repair most flooring industry specific equipment. Customers are welcome to drop off equipment at any of our warehouses or we will gladly pickup your equipment within our delivery footprint. If so inclined, our large in house inventory of parts, belts, bulbs, brushes, blades, etc. makes routine maintenance and minor repairs a relatively easy endeavor for our customers. W

1.1.3. Force Equipment are a leading provider of mechanical repairs to dirt moving equipment

Well located and equipped with the latest technology our workshop facilities are equipped to provide a cost effective solution to our clients for all mechanical repairs and earthmoving equipment maintenance. Our experienced, long term employees with extensive experience in mining equipment service and repairs ensure all jobs are completed efficiently and to a high quality.

1.1.4. Mechanical Repairs

An auto mechanic (automotive technician in most of North America, light vehicle technician in British English, and motor mechanic in Australian English) is a mechanic with a variety of automobile makes or either in a specific area or in a specific make of automobile. In repairing cars, their main role is to diagnose the problem accurately and quickly. They often have to quote prices for their customers before commencing work or after partial disassembly for inspection. Their job may involve the repair of a specific part or the replacement of one or more parts as assemblies.

Basic vehicle maintenance is a fundamental part of a mechanic's work in modern industrialized countries while in others they are only consulted when a vehicle is already showing signs of malfunction. Preventative maintenance is also a fundamental part of a mechanic's job, but this is not possible in the case of vehicles that are not regularly maintained by a mechanic. One misunderstood aspect of preventative maintenance is *scheduled replacement* of various parts, which occurs before failure to avoid far more expensive damage. Because this means that parts are replaced before any problem is observed, many vehicle owners will not understand why the expense is necessary.

Due to the increasingly labyrinthine nature of the technology that is now incorporated into automobiles, most automobile dealerships and independent workshops now provide sophisticated diagnostic computers to each technician, without which they would be unable to diagnose or repair a vehicle.

General Mechanical Repairs takes place at:-

- All aspects of mining equipment servicing
- Minor repairs to full machine overhauls
- Engine overhaul and full component rebuilds
- Hydraulic Cylinder repairs
- Site specific fit outs
- Upgrades and modifications
- Component overhaul & rebuild
- New machine assembly
- Auto electrical repairs and installations
- Large range of exchange components (engines, transmissions and brakes

Figure 1.1 mechanical repair

1.2. Adjust machine moving parts

1.2.1. Introduction

A. Machine Moving parts: - are components of structure, infrastructure or machine that physically move. They are often compared to solid state electronics that have no moving parts.

All Moving parts which subjected to sliding or rolling friction in all case lubrication is must

Generally speaking, machine with moving parts more likely to break and require more maintenance. The movement of parts tends to create friction ,heat and vibration that cause wear. Machine with large moving parts may be a safety hazard if not properly operated and maintained

B. Machine Moving parts: - are machine components excluding any moving fluids, such as fuel, coolant or hydraulic fluid.

Moving parts also do not include any mechanical locks, switches, nuts and bolts, screw caps for bottles etc. A system with no moving parts is described as "solid state".

☞ Loosen parts – those parts which are not fastened to gather or not firmly fixed

- ➢ Loosen parts should be adjusted to the standard working condition using proper adjusting tools
- ➢ Most loosen parts on machine are:-
  - ✓ Bolt &nut
  - ✓ Cooling
  - ✓ Safety guard
  - ✓ Main parts of machine
  - ✓ Gear
  - ✓ Bearing
  - ✓ Screw
  - ✓ Body of a machine

General Safety staff developed the campus Machine Guarding Safety Program to manage the safe selection, procurement, use of and safe work practices, inspection and record keeping for all machine guarding equipment and devices. Included are guidelines for identification and correction of locations with machine guarding hazards that may endanger faculty, staff, students, and the public.

This Machine Guarding Safety Program applies to any department on campus, at field stations, or on leased property where any type of activities could result in injuries from machine operation. The campus Machine Guarding Safety written program outlines roles and responsibilities for users of machinery (including fulltime employees, contract employees and graduate students performing research related activities in field stations and remote research facilities) as well as those of EH&S/***General Safety*** staff in managing this program, and "Owner Departments" that purchase, maintain and/or manage an inventory of shop, scientific, maintenance or repair machinery.

Figure 1.2. Moving machine parts

Having an understanding of how a machine works, and how the guards can protect you, will result in a reduced risk of injury. In order to be in compliance with **Cal/OSHA requirements**, all guards must:

- **Prevent contact** – machine guards must provide a physical barrier that prevents the operator from having any part of his/her body in the "danger zone" during the machine's operating cycle;
- **Be secured in place or otherwise be tamper proof** – machine guards must be secure and strong so that workers are not able to bypass, remove, or tamper with them. They must be attached to the machine where possible. If the guard cannot be physically attached to the machine it must be attached elsewhere;

- **Create no new hazard** – A safeguard defeats its own purpose if it creates a hazard of its own such as a shear point, a jagged edge, or an unfinished surface which can cause a laceration. The edges of guards, for instance, should be rolled or bolted in such a way that they eliminate sharp edges. Machine guards should not obstruct the operator's view; **Allow for lubrication with the guard still in place** - If possible, one should be able to lubricate the machine without removing safeguards. Locating oil reservoirs outside the guard, with a line leading to the lubrication point, will reduce the need for the operator or maintenance worker to enter the hazardous area.
- **Not interfere with the machine operation** - Any safeguard which impedes a worker from performing the job quickly and comfortably might soon be overridden or disregarded. Proper safeguarding can actually enhance efficiency since it can relieve the worker's apprehensions about injury.

A wide variety of mechanical motions and actions may present hazards to workers operating or working around machinery. The three basic types of hazardous mechanical motions and actions are:-

1.2.2. Types of Hazards

- **Hazardous Motions** :- including rotating machine parts, reciprocating motions (sliding parts or up/down motions), and transverse motions (materials moving in a continuous line)
- **Points of Operation**: - the areas where the machine cuts, shapes, bores, or bends the stock being fed through it.
- **Pinch Points and Shear Points**: - the area where a part of the body or clothing could be caught between a moving part and a stationary object. This would include power transmission apparatuses such as flywheels, pulleys, belts, chains, couplings, spindles, cams, gears, connecting rods and other machine components that transmit energy.

There are also non-mechanical hazards that can injure machine operators or personnel working in the vicinity of machinery. These hazards include flying splinters, chips or debris; splashes, sparks or sprays that are created when the machine is operating. These hazards can be prevented through the use of machine guarding and wearing/use of required personal protective equipment (PPE)

1.2.3. Diagnostic Technologies and measuring devices

There are five (5) general types of machine safeguards that can be used to protect workers and personnel in the immediate vicinity of machinery. They are:

1. **Guards**: - these are physical barriers that prevent contact. They can be fixed, interlocked, adjustable, or self-adjusting.
2. **Devices**: - these limit or prevent access to the hazardous area. These can be presence-sensing devices, pullback or restraint straps, safety trip controls, two-hand controls, or gates.
3. **Automated Feeding and Ejection Mechanisms**: - These eliminate the operator's exposure to the point of operation while handling stock (materials).

4 **Machine Location or Distance** :- this method removes the hazard from the operator's work area.

5 **Miscellaneous Aids** ;- these methods can be used to protect both operators and people in the immediate vicinity of operating machinery. Examples include shields to contain chips, sparks, sprays or other forms of flying debris; holding tools that an operator can use to handle materials going into the point of operation; and awareness barriers to warn people about hazards in the area.

Figure 1.3. Adjusting machine moving parts.

1.2.4. Dangerous parts of machinery

Running nips between parts rotating in opposite directions, For e.g. gear wheels.

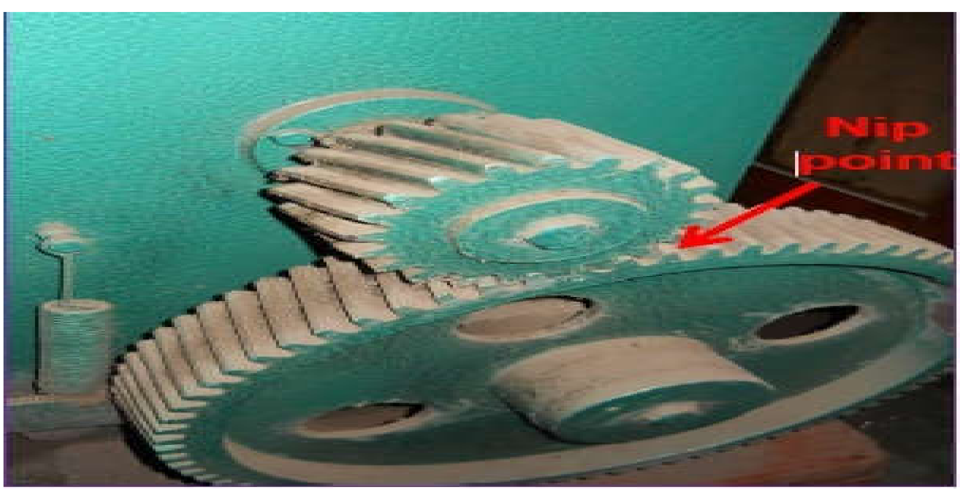

Figure 1.4. Dangerous parts of machinery on gear wheels. Between rotating and tangentially moving parts

Figure 1.5. Dangerous parts of machinery on belt drives.

Wherever there is a rotating part operating close to a fixed structure there is a danger of trapping or crushing.

- Reciprocating and sliding motions.

Figure 1.6. Machine guard

Any machine part which can cause injury must be guarded .Machine guards help to eliminate personnel hazards created by points of operation, ingoing nip points, rotating parts and flying chips.

1.2.5. Types of guards

Commonly used machine guards are

- Fixed guard
- Interlocked guard
- Adjustable guard
- Self-adjusting guard
- Pull back device
- Two-hand control

Fixed guard:-is kept in place permanently by fasteners that can only be released by the use of a tool.

Interlocked guard:-shuts off or disengages power to the machine and prevents it from starting when the guard is removed/ opened.

Adjustable guard:-provides a barrier which can be adjusted to suit the varying sizes of the input stock.

Self-adjusting guard:-provides a barrier which moves according to the size of the stock entering the danger area.

Two hand controls: -concurrent use of both hands is required to operate the machine, preventing the operator from reaching the danger area.

Pull back: -the device is attached to the wrist of the operator which pulls the operator's hands away from the point of operation or other hazardous areas when the machine operates.

1.2.6. Miscellaneous safe guarding aids.

Shields can be used to provide protection from flying particles, splashing metal working fluids or coolants.

- Holding tools can be used to place and remove stock. Example, reaching into the danger area of a power press.
- Holding tools must not be used as a replacement of machine guards.
  - ✓ Safety precautions while working with machinery
  - ✓ Ensure that the guards are in position and in good working condition before operating.
  - ✓ Know the location of emergency stop switch.
  - ✓ Do not wear loose clothing or jewelry that can be caught in the rotating parts.
  - ✓ Confine long hair.
  - ✓ The keys and adjusting wrenches must be removed from the machine before operating it.
  - ✓ Stop the machine before measuring, cleaning or making any adjustments.
  - ✓ Do not handle metal turnings by hand as they can cause injury. Use brush or rake to remove turnings.
  - ✓ Keep hands away from the cutting head and all moving parts.
  - ✓ Cutting tools and blades must be clean and sharp, so that they can be used without force.
  - ✓ Avoid awkward operations and hand positions. A sudden slip could cause the hand to move into the cutting tool or blade.
  - ✓ Keep work area clean. Floors must be level and have a non-slip surface.
  - ✓ The person working with the machine must not be distracted.

- ✓ Machines must not be left unattended. Switch off the machine before leaving.
- ✓ Rotating parts of machines must not be stopped with hands after switching off.
- ✓ There must be enough space around the machine to do the job safely.
- ✓ Compressed air must not be used to clean machines, as this can force small particles to fly off and can cause injury.
- ✓ Safety glasses must always be used while working with machinery for protection from flying particles.
- ✓ Safety glasses must be worn by all personnel entering an area where machines are operated.
- ✓ Hand gloves must NOT be used while working with machinery, due to the chances of getting caught in thenip point.
- ✓ Safe work practices –Drill press
- ✓ When making deep holes, clean the hole frequently.
- ✓ Use a clamp or drill vise to prevent work from spinning.
- ✓ The drill bit or cutting tool must be locked securely in the chuck.
- ✓ Remove the chuck key before starting the drill press.
- ✓ Lubricate drill bit when drilling metal.
- ✓ Do not force the drill with extra pressure.
- ✓ Do not hold the work by hand.
- ✓ Do not place hands under the stock being drilled
- ✓ Reduce the drilling pressure when the drill begins to break through the work piece. This prevents drill from pulling into the work and breaking.
- ✓ Scraper blades

1.2.7. Scraper Blades for Use below the Belt

Type 56/256

- Polyurethane base featuring the proven TWIST-SWING® technology with snap-in foot
- Pivoting stainless steel blade holder for optimum, individual adjustment to the conveyor belt
- Plain bearing with grease pockets for 100% reliable operation
- Special carbide blades for long service life and uniform wear
- Small contact area to the surface of the belt for perfect cleaning results achieved at lowest contact pressure
- 90° angle to the belt with towing operation for ultimate belt-saving operation
- Also available in ATEX design and for food applications
- Scraper segments in long and short versions with overlapping blades to ensure efficient cleaning across the entire scraping width
- PU aprons protect the blade base against the scraped material
- Type 256 in double width available

Figure 1.7. Scraper blades

1.3. Undertake removal/ replacement of consumable components

1.3.1. Introduction

Consumables are goods used by individuals and businesses that must be replaced regularly because they wear out or are used up. They can also be defined as the components of an end product that is used up or permanently altered in the process of manufacturing such as semiconductor wafers and basic chemicals

Repairable parts are parts that are deemed worthy of repair, usually by virtue of economic consideration of their repair cost. Rather than bear the cost of completely replacing a finished product, repairable typically are designed to enable more affordable maintenance by being more modular. This allows components to be more easily removed, repaired, and replaced, enabling cheaper replacement. Spare parts that are needed to support condemnation of repairable parts are known as *replenishment* spares.

Ratable pool is a pool of repairable spare parts inventory set aside to allow for multiple repairs to be accomplished simultaneously. This can be used to minimize stock out conditions for repairable items

Replacing consumables

The consumables used with office equipment, such as paper and toner need to be replaced at certain times. For example, the paper in a printer will need to be replenished when it has run out. In this example the printer will normally display a message indicating that the paper has run out and needs to be replaced. Other equipment will also provide messages indicating that consumables need to be replaced.

For example, the fax machine will usually indicate that the paper supply needs to be replaced and the photocopier may indicate when the toner needs to be replaced. Clearly when these messages appear you will need to take the appropriate action by following the manufacturer's instructions.

On occasions equipment will not display a message even though a consumable needs to be replaced. For example, if your photocopier has a stapling function it may not display when the supply of staples has ended.

In many cases the action you need to take to replace the consumables will be obvious, but if it is not then you can consult the User Manual, which will indicate what needs to be done.

Each piece of office equipment will also have components, such as rollers in a photocopier, that need to be replaced by a technician. If a component needs to be replaced then ensure that you follow any policies and procedures when contacting the technician. For example, your firm may have a maintenance contract in place with a specific firm.

Ceramic foam filter:-is just developed as a new type of molten metal ***filter***s to decrease casting flaw in recent years. We can supply ***ceramic foamfilter***s are Specifications ***Ceramic foam filter***:

Figure 1.8. **Ceramic foam filter**

1.3.2. Air filter

Air filters are cleaning devices that capture unwanted, sometimes harmful pollutants from the air circulating in your home. They are essential components of forced-air HVAC (heating, ventilation and air conditioning) systems. With indoor air pollution as one of the top five environmental health risks, it is important that homes have adequate ventilation and clean air to help control or eliminate the potentially harmful elements.

Air filters ultimately help filter out allergens, pet dander, dust, fumes, odors, and other small particles that can affect the lungs. Additionally, air filters should be routinely monitored and changed to maximize comfort for those indoors.

Figure 1.9. Air filter

1.3.3. Tooltips

Documentation and examples for adding custom Bootstrap tooltips with CSS and JavaScript using CSS3 for animations and data-attributes for local title storage.

Things to know when using the tooltip plugging:

Tooltips rely on the 3rd party library Popper.js for positioning. You must include popper. Min.js before bootstrap.js or use bootstrap. bundle. min.js / bootstrap. bundle.js which contains Popper.js in order for tooltips to work!

If you're building our JavaScript from source, it requires util.js.

Tooltips are opt-in for performance reasons, so you must initialize them yourself.

Tooltips with zero-length titles are never displayed.

Specify container: 'body' to avoid rendering problems in more complex components (like our input groups, button groups, etc).

Triggering tooltips on hidden elements will not work.

Tooltips for .disabled or disabled elements must be triggered on a wrapper element.

When triggered from hyperlinks that span multiple lines, tooltips will be centered. Use white-space: nowrap; on your <a>s to avoid this behavior.

Tooltips must be hidden before their corresponding elements have been removed from the DOM.

1.3.4. Lubrication

- ✓ Lubrication is the control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact. The lubricant used can be a fluid, solid, or plastic substance.

- ✓ Although this is a valid definition, it fails to realize all that lubrication actually achieves.
- ✓ Many different substances can be used to lubricate a surface. Oil and grease are the most common. Grease is composed of oil and a thickening agent to obtain its consistency, while the oil is what actually lubricates. Oils can be synthetic, vegetable or mineral-based as well as a combination of these.

1.3.5. Stock levels

In order for consumables to be available when required it is important that appropriate stock levels are maintained. Not having consumables in stock can cause a piece of equipment to become inoperable leading to serious problems for the completion of work. For example, if enough paper is not available then the photocopier and the computer printers could all be out of action at the same time.

The usage of consumables should be monitored over time so that appropriate stock levels can be maintained. This should ensure that enough stock is available to cover most situations.

1.3.6. Cleaning equipment

It is important that equipment is cleaned regularly following the guidelines suggested by the manufacturer. Cleaning equipment properly helps ensure that equipment works efficiently and that maintenance costs are kept to a minimum.

When cleaning a piece of equipment you should:

1. Use the types of tools suggested by the manufacturer, for example, the correct cloths or brushes should be used for photocopiers
2. Use the cleaning fluids suggested by the manufacturer
3. Ensure that a regular cleaning schedule is established and followed.

1.4. Replace /topping up fluids and lubricants

1.4.1. Introduction

Lubrication and Lubricating fluid should be replaced by new one after recommended period of time.

Why Lubrication and fluid should be changed? Because each lubrication (lubricant) and lubricating oil has its own lubricating time recommended by the manufacturer and the oil have their own viscosity.

Lubricant and fluid should be topped according to the prescribed schedule by manufacturer of a machine based on working time of the given machine

Liquid lubricants have been around for a long time and have evolved from the conventional mineral-oil based to the more exotic synthetics. In this chapter, a systematic approach to the selection of a lubricant will be addressed. The evolution of the base oil technology for the conventional lubricants will be discussed in detail. Different classes of the synthetic-based specialty and high-temperature lubricants and their key features will also be addressed. The purpose of this manual is to aid the machine operator in the selection of suitable hydraulic fluid, gear lubricants, gear bearing grease, preservation fluid and petroleum jelly.

The specifications of the lubricant manufacturer and the recommendations of the machine manufacturer are the basis for selection and subject to change without advance advice. The choice of suitable hydraulic fluids or lubricants is critical for the lifetime, operational safety and efficiency of hydrostatic components and gears.

Lubrication is the control of friction and wear by the introduction of a friction-reducing film between moving surfaces in contact. The lubricant used can be a fluid, solid, or plastic substance.

Although this is a valid definition, it fails to realize all that lubrication actually achieves.

Many different substances can be used to lubricate a surface. Oil and grease are the most common.

1.4.2. The primary functions of a lubricant are to:

The primary function of a lubricant is to **prevent friction by creating a boundary layer between two surfaces**

a) Reduce friction
b) Prevent wear
c) Protect the equipment from corrosion
d) Control temperature (dissipate heat)
e) Control contamination (carry contaminants to a filter or sump)
f) Transmit power (hydraulics)

1.4.3. A good lubricant generally possesses the following characteristics:

Lubricants are the lifeblood of mechanical assets, forming a protective layer between moving parts to minimize friction, maintain productivity and prevent unplanned downtime. Choosing a good lubricant is a critical part of any asset management and maintenance strategy.

1. A high boiling point and low freezing point (in order to stay liquid within a wide range of temperature)
2. A high viscosity index
3. Thermal stability
4. Hydraulic stability
5. Corrosion prevention
6. A high resistance to oxidation

1.5. Undertake safety program and maintenance

1.5.1. Introduction

This standard describes the skills, knowledge and understanding required to demonstrate competence in undertaking the in-process accuracy checking of assembled prescribed items against prescriptions received from individuals prior to the final accuracy check of a prescription.

What is an in process check?

In-Process Control refers to the checks performed during an activity (it can be manufacturing or packing) in order to monitor and if necessary to adjust the process and/or to ensure that the intermediate or finished product conforms to its specification.

1.5.2. Safety and Maintenance Checks

University Housing conducts Safety and Maintenance checks prior to Thanksgiving Break, Winter Break, and Spring Break to ensure safety and security during periods of low occupancy. During checks, staff members will report any electrical/fire safety or policy concerns.
Students do NOT need to be present when their rooms are checked.
As you prepare for Breaks (Thanks giving, winter, and spring), please be sure and do the following:

- Close and lock ALL windows and doors.
- Close drapes and blinds.
- Turn off heaters.
- Turn off and unplug alarm clocks, stereos, and computers.
- Remove perishable food items, including emptying trash/recycling.

1.5.3. Machine Guards

We’ve all had the very frustrating experience of doing what we thought was a favor for someone only to have it rejected or go unappreciated. I suppose if machine guards were human, they would experience this sort of frustration frequently.

While the basic motive for guarding is to protect, not prohibit, guards are often looked upon by employees as obstacles. However, guards are for your protection-regardless of what kind they are or where they are placed.

Specifically, machine guards are used to protect against direct contact with moving parts. There are also guards designed to protect against flying chips, kickbacks, and splashing of metal or harmful liquids. Mechanical and electrical failures are also guarded against in many situations.

1.5.4. Machine and Equipment Guarding Procedures

a) Guards - Barriers which prevent access to danger areas. There are four general types of guards: fixed, interlocked, adjustable, self-adjusting.
b) Pinch Points - Points at which it is possible to be caught between moving parts, or between moving and stationary parts of a piece of equipment.
c) Point of Operation - The point of operation is where work is performed on the material, such as cutting, shaping, boring, or forming of stock.
d) Power Transmission Device - The power transmission apparatus is all components of the mechanical system which transmit energy to the part of the machine performing the work. These components include flywheels, pulleys, belts, connecting rods, couplings, cams, spindles, chains, cranks, and gears.
e) Operating Controls - A mechanical or electrical power control shall be provided on each machine to make it possible for the operator to cut off the power from each machine without leaving his position at the point of operation.

The following procedures, information, and resources will assist managers, supervisors, and operators in carrying out their responsibilities for assuring safety through hazard identification and evaluation, safeguarding, training, and safe operation of machines and equipment.

These procedures are intended to:-

a. Create an awareness of the hazards among the workforce.
b. Standardize procedures for the use and care of machines and equipment.
c. Provide a consistent format for training employees on the proper procedures for operating and using machines and equipment.
d. Minimize the possibility of injury or harm.
e. Demonstrate compliance with safety regulations.

1.6. Record status report

1.6.1. Introduction

This section provides guidance to a practitioner who is engaged to issue or does issue an examination or a review report on pro forma financial information. Such an engagement should comply with the general and fieldwork standards set forth in section 101, ***Attest Engagements***, and the specific performance and reporting standards set forth in this section.

Note: In connection with an engagement performed in accordance with this attestation standard, whenever the practitioner is required to make reference in a report to attestation standards established by the American Institute of Certified Public Accountants, the practitioner must instead refer to "the standards of the Public Company Accounting Oversight Board (United States)." A practitioner must also include the city and state (or city and country, in the case of non-U.S. practitioners) from which the practitioner's report has been issued.

What is pro forma reporting?
In accounting, pro forma refers to a report of the company's earnings that excludes unusual or nonrecurring transactions. Excluded expenses could be declining investment values, restructuring costs, and adjustments made on the company's balance sheet that fix faulty accounting practices from other years
The objective of pro forma financial information is to show what the significant effects on historical financial information might have been had a consummated or proposed transaction (or event) occurred at an earlier date.

Pro forma financial information is commonly used to show the effects of transactions such as the following:
• Business combination
• Change in capitalization

1.6.2. Reporting on Pro Forma Financial Information

Relating to the pro forma financial information is affected by the scope of the engagement providing the practitioner with assurance about the underlying historical financial information to which the pro forma adjustments are applied. Therefore, the level of assurance given by the practitioner on the pro forma financial information, as of a particular date or for a particular period, should be limited to the level of assurance provided on the historical financial statements (or, in the case of a business combination, the lowest level of assurance provided on the underlying historical financial statements of any significant constituent part of the combined entity).

For example, if the underlying historical financial statements of each constituent part of the combined entity have been audited at year-end and reviewed at an interim date, the practitioner may perform an examination or a review of the pro forma financial information at year-end but is limited to performing a review of the pro forma financial information at the interim date.

The practitioner who is reporting on the pro forma financial information should have an appropriate level of knowledge of the accounting and financial reporting practices of each significant constituent part of the combined entity. This would ordinarily have been obtained by the practitioner auditing or reviewing historical financial statements of each entity for the most recent annual or interim period for which the pro forma financial information is presented. If another practitioner has performed such an audit or a review, the need, by a practitioner reporting on the pro forma financial information, for an understanding of the entity's accounting and financial reporting practices is not diminished, and that practitioner should consider whether, under the particular circumstances, he or she can acquire sufficient knowledge of these matters to perform the procedures necessary to report on the pro forma financial information.

1.6.3. Practitioner's Objective

The objective of the practitioner's examination procedures applied to pro forma financial information is to provide reasonable assurance as to whether

- Management's assumptions provide a reasonable basis for presenting the significant effects directly attributable to the underlying transaction (or event).
- The related pro forma adjustments give appropriate effect to those assumptions.
- The pro forma column reflects the proper application of those adjustments to the historical financial statements.
- The objective of the practitioner's review procedures applied to pro forma financial information is to provide negative assurance as to whether any information came to the practitioner's attention to cause him or her to believe that
- Management's assumptions do not provide a reasonable basis for presenting the significant effects directly attributable to the underlying transaction (or event).
- The related pro forma adjustments do not give appropriate effect to those assumptions.

1.6.4. Procedures

Other than the procedures applied to the historical financial statements, the procedures the practitioner should apply to the assumptions and pro forma adjustments for either an examination or a review engagement are as follows.

(a). Obtain an understanding of the underlying transaction (or event), for example, by reading relevant contracts and minutes of meetings of the board of directors and by making inquiries of appropriate officials of the entity, and, in cases, of the entity acquired or to be acquired.

(b). Obtain a level of knowledge of each constituent part of the combined entity in a business combination that will enable the practitioner to perform the required procedures. Procedures to obtain this knowledge may include communicating with other practitioners who have audited or reviewed the historical financial information on which the pro forma financial information is based. Matters that may be considered include accounting principles and financial reporting practices followed transactions between the entities, and material contingencies.

(c). Discuss with management their assumptions regarding the effects of the transaction (or event).

(d). Evaluate whether pro forma adjustments are included for all significant effects directly attributable to the transaction (or event).

(e). Obtain sufficient evidence in support of such adjustments. The evidence required to support the level of assurance given is a matter of professional judgment. The practitioner typically would obtain more evidence in an examination engagement than in a review engagement. Examples of evidence that the practitioner might consider obtaining are purchase, merger or exchange agreements, appraisal reports, debt agreements, employment agreements, actions of the board of directors, and existing or proposed legislation or regulatory actions.

(f). Evaluate whether management's assumptions that underlie the pro forma adjustments are presented in a sufficiently clear and comprehensive manner. Also, evaluate whether the pro forma adjustments are consistent with each other and with the data used to develop them.

(g). Determine that computations of pro forma adjustments are mathematically correct and that the pro forma column reflects the proper application of those adjustments to the historical financial statements.

(h). Obtain written representations from management concerning their Responsibility for the assumptions used in determining the pro forma adjustments

Assertion that the assumptions provide a reasonable basis for presenting all of the significant effects directly attributable to the transaction (or event), that the related pro forma adjustments give appropriate effect to those assumptions, and that the pro forma column reflects the proper application of those adjustments to the historical financial statements

Self-check-1

Direction: Answer the following questions below.

Part-I. choose the best answers

1. Which one of the following is Inspection Machines are a series of machine including :-

   A. Manual, mechanical
   C. Computerized electronic systems
   B. A and B are answers
   D. D. None of the above

2. Which one of the evidence of leakage, from dampness to oil puddles, should be noted and corrected means.
   A. Reservoirs and sumps are clean and free of water and sludge.
   B. Shafts are being rotated frequently.
   C. Dirt and other debris have not accumulated on exterior surfaces
   D. All of the above are answers

3. Which one of is allow you to access those hard-to-reach machine conditions and frictional surfaces.
   A. Stop Inspection
   C. Repair inspection
   B. run inspection
   D. all of the above
4. which one of the following are Mechanical Repairs
   A. All aspects of mining equipment servicing
   B. Minor repairs to full machine overhauls
   C. Engine overhaul and full component rebuilds
   D. All of the above are answers
5. which one of the following are Mechanical Repairs
   A. Component overhaul & rebuild
   B. New machine assembly
   C. Auto electrical repairs and installations
   D. None of the above
6. which one of the following are Purpose of Maintenance
   A. Prevent breakdown or failures
   B. Maximizing production loss from failures
   C. De creasing reliability of the operating systems
   D. All of the above
7. which one of the following are Causes of accidents while working with machinery
   A. Materials ejected from the machine when it is operational.
   B. Inadvertent starting of the machine.
   C. Slipping and falling into an unguarded nip
   D. All of the above are answers

8. which one of the following are Safety precautions while working with machinery
   A. Keep work area clean. Floors must be level and have a non-slip surface.
   B. The person working with the machine must not be distracted.
   C. Machines must not be left unattended. Switch off the machine before leaving
   D. None of the above
9. which one of the following are Safety precautions while working with machinery
   A. Ensure that the guards are in position and in good working condition before operating.
   B. Know the location of emergency stop switch.
   C. Do not wear loose clothing or jewelry that can be caught in the rotating parts.
   D. All of the above are answers
10. _____ kept in place permanently by fasteners that can only be released by the use of a tool.
    A. Fixed guard
    B. Interlocked guard
    C. Adjustable guard
    D. Self adjusting guard
11. When making deep holes, clean the hole frequently.
    A. Use a clamp or drill vise to prevent work from spinning.
    B. The drill bit or cutting tool must be locked securely in the chuck.
    C. Remove the chuck key before starting the drill press.
    D. All of the above are answers.
12. ___ the device is attached to the wrist of the operator which pulls the operator's hands away
    A. Fixed guard
    B. Interlocked guard
    C. Pull back
    D. Self adjusting guard
13. Which one the following substances can be used to lubricate a surface.
    A. Oil and grease.
    B. Dust piratical Thermal stability
    C. Corrosion prevention
    D. A high resistance to oxidation
14. Which one the following is advantage of lubrication
    A. Control of friction and wear
    B. A friction-reducing film
    C. A friction-reducing film
    D. all of the above
15. The primary functions of a lubricant are to:-
    A. Control temperature (dissipate heat)
    B. Control contamination (carry contaminants to a filter or sump)
    C. Transmit power (hydraulics)
    D. All of the above are answers
16. ____ Barriers which prevent access to danger areas.
    A. *Guards*
    B. Point of Operation
    C. Pinch Points
    D. Power Transmission Device.

17. ___ the point of operation is where work is performed on the material
    A. Guards
    B. Point of Operation
    C. Pinch Points
    D. Power Transmission Device.
18. Which one of the following are procedures are intended
    A. Create an awareness of the hazards among the workforce.
    B. Minimize the possibility of injury or harm.
    C. Demonstrate compliance with safety regulations
    D. All of the above

Test-II: say **true** if the statement is correct **false** if the statement is in correct

1. Construction regulations require inspections of vehicles, tools, machines and equipment before use.
2. Preventive maintenance is the systematic care and protection of tools, equipment, machines.
3. Most manufacturers can provide maintenance schedules for their equipment.
4. Flooring insured, service center for all your flooring equipment repairs and maintenance.
5. maintenance machinists, keep machines in working order by detecting and correcting errors
6. The consumables equipment is used office and shop.
7. Always a good idea to at least check your air filters at every oil change.
8. If a component needs to be replaced then ensure that you follow any policies and procedures when contacting the technician.
9. Pro forma refers to none report of the company's earnings that exclude unusual or nonrecurring transactions.
10. The related pro forma adjustments give appropriate effect to those assumptions.

Part-III:-write and explain

1. Explain all about Repair?
2. What are the types of Maintenance?
3. How do you maintain safety in the workplace?
4. What is maintenance process?
5. What is a company safety program?
6. What are the types of maintenance?
7. What are maintenance practices?
8. What is maintenance and why is it necessary?

Operation sheet:-1

Techniques of Performing Inspecting Machines/equipment

Operation Title: -Inspecting Machines/equipment

Purpose: This activity will develop the skill, knowledge and attitude of the students to inspecting Machines/equipment operation using the lathe machine.

Method manually Inspecting Machines/equipment.

Procedure or Step

Step 1: Wear properly personal protective equipment (PPE)

Step 2: Use properly Tools, Materials, &equipment.

Step 3: Identify Hazardous Energy

Step 4: Communicate

Step 5: Shut-down

Step 6: Isolate

Step 7: Apply LO/TO device(s)

Step 8: Relieve Stored Energy

Step 7: Verify

Step 9: Service

Step 10: Inspect

Step 11: Remove LO/TO (lockout/tag out)

Step 12: Communicate

Step 13: Restart

Operation sheet:-2

Techniques of Performing minor machine repairs

Operation Title: - repairs lathe machine**.**

Purpose: This activity will develop the skill, knowledge and attitude of the students to Maintaining tools and Equipment operation using the lathe machine.

Method manually repairs lathe machine.

Procedure or Step

1. Wear properly personal protective equipment (PPE)
2. Use properly Tools, Materials, &equipment.
3. Disconnect electric from the source
4. Check that all moving part is well lubricated or not
5. Clean the surface of the spindle, turret and the body of the machine
6. Remove the damage or broken machine part
7. Replace or repair the new one
8. Check the operation of the manually operated
9. Check the wear of the guide rails
10. Check the Replace or repair parts work properly
11. Finalize over all about the machine

Operation sheet:-3

Procedures of Adjusting machine moving parts

Operation Title: -Adjusting machine moving parts.

Purpose: This activity will develop the skill, knowledge and attitude of the students to Maintaining tools and Equipment operation using the lathe machine.

Method manually adjusting machine moving parts.

Procedure or Step

1. Wear properly personal protective equipment (PPE)
2. Use properly Tools, Materials, &equipment.
3. Disconnect electric from the source
4. Check that all moving part is well lubricated or not
5. Clean the surface of the spindle, turret and the body of the machine
6. Identify the misalignment of moving machine part
7. Adjusting the misalignment of moving machine part
8. Check the operation of the manually operated
9. Check the misalignment of moving machine part work correctly
10. Finalize over all about the machine

Unit Two: Preventive Maintenance

This unit to provide you the necessary information regarding the following content coverage and topics:

- role and responsibilities in Maintenance
- Functionality of tools and equipment
- documentation of defective hand tools and equipment
- lubrication on tools and equipment
- Preparation and ways of Maintenance reporting

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Identifying and recognizing individual role and responsibilities within the team
- Making effective and appropriate contributions to complement team activities
- Checking tools and equipment
- Reporting defective hand tools and equipment
- Cleaning and lubricating tools and equipment
- Identifying report relationships within team and external to team
- Accomplishing necessary reports

2. Preventive Maintenance

2.1. Role and Responsibilities in Maintenance

2.1.1. General Maintenance introduction

The prime motivator in manufacturing, especially as it pertains to equipment maintenance, is to keep production running in high gear. Maintenance directly affects the productivity, quality, and direct costs of production. Yet, today the most commonly practiced approach to maintenance continues to be purely reactive (i.e., an almost universal focus on equipment breakdowns). This *breakdown maintenance* mentality stands in direct opposition to the target of high productivity.

To keep production in high gear and to survive manufacturers are increasingly obliged to move from a breakdown maintenance mindset toward a concept of proactive maintenance organized around a well-trained staff, within a carefully defined plan, and with meaningful participation of employees outside of what is normally thought of as traditional maintenance. It's a move toward a total team approach of effective preventive maintenance and total quality management (TQM).

At the core of world-class maintenance is a new partnership among the manufacturing or production people, maintenance, engineering, and technical services to improve what is called overall equipment effectiveness (OEE). It is a program of zero breakdowns and zero defects aimed at improving or eliminating the six crippling shop-floor losses:

- Equipment breakdowns
- Setup and adjustment slowdowns
- Idling and short-term stoppages
- Reduced capacity
- Quality-related losses
- Startup/restart losses

2.1.2. Fundamentals of Maintenance

The five fundamentals of maintenance approach include improving equipment effectiveness, involving operators in daily maintenance, improving maintenance efficiency and effectiveness, educating and training, and designing and managing equipment for maintenance prevention.

A. **Improving Equipment Effectiveness:** finding out what causes your equipment to be ineffective and making improvements.

B. **Involving Operators in Daily Maintenance:** In many successful programs, operators do not have to actively perform maintenance. They are involved in the maintenance activity in the plan, in the program, in the partnership, but not necessarily in the physical act of maintaining equipment.

C. **Improving Maintenance Efficiency and Effectiveness:** The operator is directly involved in some level of maintenance. This effort involves better planning and scheduling, better preventive maintenance, predictive maintenance, reliability-centered maintenance, spare parts equipment stores, tool locations

D. **Educating and Training:** Operators are taught how to operate their machines properly and maintenance personnel to maintain them properly. Because operators will be performing some of the inspections, routine machine adjustments, and other preventive tasks, training involves teaching operators how to do those inspections and how to collaborate with maintenance. Also involved is training supervisors on how to supervise in a proactive-type team environment.

E. **Designing and Managing Equipment for Maintenance Prevention:** Equipment is costly and should be viewed as a productive asset for its entire life. Designing equipment that is easier to operate and maintain than previous designs is a fundamental part of proactive performance. Suggestions from operators and maintenance technicians help engineers design, specify, and procure equipment that is more effective. By evaluating the costs of operating and maintaining the new equipment throughout its life cycle, long-term costs will be minimized.

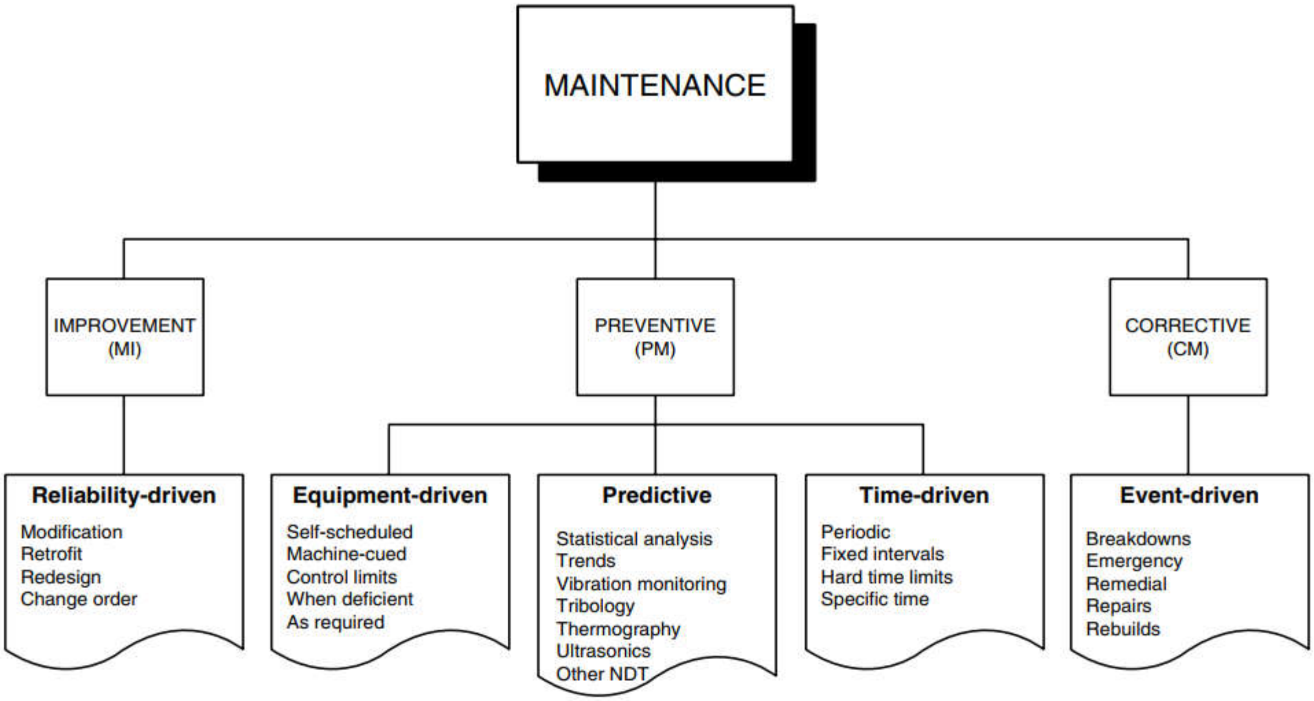

Figure 2.1. Structure of maintenance.

Contrary to popular opinion, the role of maintenance is not to "fix" breakdown in record time; rather, it is to prevent all losses that are caused by equipment or system related problems. The mission of the maintenance department in organization is to achieve and sustain the following:

- Optimum availability
- Optimum operating conditions
- Maximum utilization of maintenance resources
- Optimum equipment life
- Minimum spares inventory
- Ability to react quickly

2.1.3. Functional Roles and Responsibilities

Each of the functional groups that comprise the plant or corporate team has clearly defined roles and responsibility that must be effectively performed and coordinated with other functions. Each function should sit down with the other functions that they deal with on a regular basis and develop service-level agreements that spell out their roles and responsibilities to the other in order to ensure success. Typical roles and responsibilities include operations, maintenance, and engineering.

Roles and Responsibilities of Operations

A critical part of the functional partnerships is clearly defined roles and responsibilities. Operations must provide effective coordination and support with other functional groups that directly influence or are influenced by its actions.

Maintenance. The operations or production function has explicit responsibilities that must be provided before maintenance can achieve and sustain world-class performance. These responsibilities include

- Operate machinery and equipment properly.
- Know the conditions and performance of facilities and equipment.
- Maintain surveillance thereof in order to detect unsatisfactory conditions and anticipate essential work.
- Report malfunctions to appropriate engineering or maintenance personnel for diagnosis and action.
- Authorize and describe clearly in writing the repairs, replacements, and alterations. Avoid unnecessary work and fictitious priority. Help to control the volume variance within maintenance budgets.
- Participate in backlog management using a clearly defined and agreed upon set of priorities, and participate in repetitive failure analysis, using cause codes and effective analysis techniques. Accept equipment ownership.
- Participate in performance of maintenance work to the degree specified, authorized, and trained for.
- Plan for and provide adequate equipment access for timely performance of programmed and scheduled maintenance.
- Communicate the necessary capacity specifications for systems and equipment.

Roles and Responsibilities of Maintenance

The maintenance function must not only perform its duties effectively, but also provide direct coordination and support with other functional groups.

Operations. The maintenance organization must also meet its responsibilities. These include

- Based on authorized requests for maintenance service, define and execute the required work in a timely fashion, with quality workmanship; knowing what is to be done and when and how to do it best. Then do it right, the first time.

- Assist operations in establishing a practical level of maintenance so that long- and short-term operating plans can be met and repairs can be anticipated, planned, and scheduled.
- Maintain facilities at specified levels of operating condition, at lowest possible cost consistent with the goals of producing a quality product as economically as possible.
- Actively participate with production to create and implement a comprehensive preventive maintenance program.
- Convert emergency work to planned work by anticipating it.
- Make repairs and replacements at intervals required for optimal operating efficiency and in a manner creating as little production loss as possible.
- Constantly strive to improve maintenance work methods, completeness, and neatness with the goal of quality work at minimal cost.
- Effectively plan, schedule, and coordinate maintenance work with production, far enough in advance to permit them to plan for out-of-service equipment and to minimize nonproductive time and production shortages.
- Prior to execution, thoroughly review all shutdown work with key production personnel so their intimate knowledge can be fully utilized.
- Prior to start up, review the repairs made and any circumstances of note with the operations personnel in the area.
- Provide regular feedback regarding status of work requests and completion promises.
- Advise production personnel as to the levels of risk and the potential costs related to operating equipment believed to be close to failure.
- Develop techniques for predicting failure of critical facilities with reasonable accuracy.
- Inform operating personnel of facilities requiring excessive maintenance and take appropriate action to reduce it.
- Account for the level of cost incurred in the performance of requested maintenance (standard vs. actual—the performance variance).
- Regard operations as a customer (internal).
- Sponsor and participate in repetitive failure analysis sessions, with the goal of eliminating repetitive failures and isolating the behavioral or mechanical causes of these failures.

Engineering. The maintenance function has several responsibilities to engineering that will enable reliable designs to be implemented:

- Input on plant standard equipment and components
- Realistic assessment of necessary redundancy (not everything requires an installed spare).
- Participation on the design team to identify potential reliability and maintainability issues
- Commissioning assistance to enable thorough check-out of equipment prior to startup
- Realistic maintainability requirements (access platforms and overhead monorails aren't necessary everywhere)
- Resources to conduct or witness performance testing in vendor facilities prior to machine acceptance

Procurement. To enable the procurement function to be effective, the maintenance organization needs to provide:

- Reliability specification information so effective vendor negotiations can be held
- Input on supplier and/or material performance (let us know when it's not right)
- Assistance in minimizing quantities of stocked material
- Compliance with stores procedures to enable that function to work effectively
- Set up *bills of material* so that the right parts can be acquired
- Input on obsolete stocked items
- Realistic delivery requirements
- Proactive work process (enables just-in-time procurement)
- Information to file warranty claims

Roles and Responsibilities of Engineering

Maintenance. The plant or project engineering organization has several responsibilities to maintenance to ensure adequate reliability of newly installed assets:

- Design for lowest life-cycle cost instead of lowest installed cost
- Design for reliability and maintainability
- Up-front failure modes and effects analysis to identify potential design changes that may reduce the need for maintenance
- Standardization of components to reduce the need to stock additional parts in the storeroom and to reduce future training requirements

- Vendor input on maintenance strategies, failure modes, mean time between failures (MTBF), and spare parts requirements for all components
- Computerized maintenance management system (CMMS) records updates for all newly installed equipment
- Technical documentation to enable proper preventive or predictive strategy definition as well as to enable planning of future corrective work
- Test and inspection results from performance test at the vendor's facility
- Installation in accordance with good reliability practices, such as good piping alignment, adequate foundation mass, and the like

Roles and Responsibilities of Procurement

Maintenance. The procurement function has several responsibilities to the maintenance organization to enable maximum reliability of equipment: The right materials in the right place at the right time (and the right price!)

- Commitment to the lowest total cost of ownership rather than lowest initial price
- Commitment to standardization of components to reduce training needs
- Hold vendors accountable for performance:
- Compliance to specifications
- On-time delivery
- Effective storeroom layout to enable critical parts to be easily located
- Prekitting and delivery services
- Identification of components under warranty so that claims can be made if necessary

2.1.4. Scope of Roles and Responsibilities

Though the actual maintenance practice may be unique to a specific facility, specific industry, or a specific set of problems and traditions, it is still possible to group maintenance activities and responsibilities into two general classifications: primary maintenance functions that demand attention and execution on daily or regular basis, and secondary ones that are performed for expediency, ability, or precedent.

A. Primary Functions

Maintenance of Existing tools/equipments. The primary role of maintenance is to sustain the reliability and operating condition of existing tools/equipments. This activity represents the physical reason for the existence of the maintenance professional. Responsibility here is simply

to execute tasks in a timely manner that prevents deterioration or damage of tools/equipments in order that they remain in a mean state of reliability that fully supports the industry mission. For this, a staff of skilled, motivated maintenance engineers, planners, and technicians is essential to apply economically effective sustaining maintenance activities,
e.g., preventive, periodic replacement and overhauls.

Maintenance of Existing workshop. Maintenance of workshop and the external property of the work area —work way, weld station, in-workshop drain systems, and water supply facilities— are among the duties generally assigned to the maintenance function. Additional aspects of buildings and grounds maintenance may be included in this area of responsibility. A shop with an extensive office facility and a major workshop-maintenance program may assign this coverage to a special team. In workshop where many of the buildings are disperse, the care and maintenance of this large amount of land may warrant a special organization.

Repairs and minor alterations to workshop—ventilate roofing, painting, Mesh wire replacement—or the unique craft skills required to service mechanical or electrical systems or the like are most logically the purview of maintenance engineering personnel. Weld area repairs and the maintenance of cylinder carry tracks and switches, weld material periparation room, or outlying structures may also be so assigned. It is important to isolate cost records for general cleanup from routine maintenance and repair so that management will have a true picture of the actual expense required to maintain the plant and its equipment.

Equipment Inspection and Lubrication. Traditionally, all equipment/tools inspections and lubrication has been assigned to the maintenance organization or function. While inspections that require special tools or partial disassembly of equipment must be retained within the maintenance function, the use of trained operators or production personnel in this critical task will provide more effective use of workshop personnel. The same is true of lubrication. Because of their proximity to the production systems, operators are ideally suited for routine lubrication tasks.

Utilities, Generation, and Distribution. In any plant generating its own electricity and providing its own process steam, the powerhouse assumes the functions of a small public utilities company and may justify an operating department of its own. However, this activity logically falls within the realm of maintenance engineering. It can be administered either as a separate function or as part of some other function, depending on management's requirements.

B. Secondary Functions

Maintenance, Repair, and Overhaul (MRO) Inventory Management. In most technical training center, it is essential to differentiate between mechanical stores and general stores. The administration of mechanical stores normally falls within the maintenance function's area because of the close relationship of this activity with other maintenance operations. Maintenance engineering has the responsibility to ensure that the proper materials are included in the MRO inventory.

Plant Protection. This category usually includes two distinct subgroups: guards or watchmen and fire-control squads. Incorporation of these functions with maintenance engineering is generally common practice. The inclusion of the fire-control group is important since its members are almost always drawn from the craft elements.

Waste Disposal. This function and that of yard maintenance are usually combined as specific assignments of the maintenance department.

2.1.5. Responsibilities of Reliability and Maintenance Engineering

Reliability engineering is primarily concerned with application of technical skills and ingenuity to the correction of equipment problems causing excessive production downtime and maintenance work. The position is dedicated to the maintenance function and is focused on the elimination of repetitive failure.

- Ensure maintainability of new installations.
- Identify and correct chronic and costly equipment problems and eliminate repetitive failure.
- Technical advice to maintenance and partners.
- Design and monitor an effective and economically justified preventive or predictive maintenance programs.
- Proper operation and care of equipment.
- Comprehensive lubrication program.
- Inspection, adjustments, parts, replacements, overhauls, and the like for selected equipment.
- Vibration and other predictive analyses.
- Protection from environment.
- Maintain and analyze equipment data and history records to predict maintenance needs.

Maintenance Engineering The role of maintenance engineering function is more tactical in nature, for example, ensuring that the assets within a plant meet the present demands of the company. Where the reliability engineer is looking at the long-term reliability needs, the maintenance engineer is handling the day-to-day reliability responsibilities.

Responsibilities of Position

- Identify, initiate, coordinate, and complete tactical maintenance and process improvement opportunities.
- Technical support of operations or maintenance in assigned area, for example, trouble-shooting, turnaround scoping, spares management, and so on.
- On new projects, assist project engineering with development and implementation of control plans, that is, criticality, preventive maintenance plan, spares, quality, maintainability, and operability.
- On existing assets, perform periodic reviews and upgrade and modify control plans.
- Communicates with reliability engineering to ensure long-term operations and maintenance asset problems are appropriately investigated with solutions implemented.
- Assist operations or maintenance management with department budgeting and expenditure forecasting.
- Continuously track and evaluate operations or maintenance expenditures, for example, cost and labor hours to ensure effective resource utilization.
- Facilitate positive change in the maintenance organization by proactively leading department initiatives. Act as a change agent in implementing cross-functional plant business objectives.
- Generate the maintenance reports for area of responsibility.
- Completions of environmental health and safety (EHS) tasks, including excavation permits, preliminary hazard analysis (PHA), and the like
- Develop, implement, and survey best practices within area of responsibility, that is, preventive maintenance practices, operating methods, and the like.
- Review major purchases to ensure correct specifications and design.
- Initiate, develop, and review capital improvement projects.
- Generate the monthly maintenance report for area of responsibility.
- Back up for maintenance supervisor.

2.1.6. Organization and Management of the Maintenance Function

As part of a proactive operation and maintenance philosophy, the maintenance engineering group is responsible for the development, implementation, and periodic evaluation of an effective asset maintenance plan (AMP). The objective of AMP plan is to

- Maintain the function in terms of the required safety.
- Maintain the inherent safety and reliability levels.
- Optimize the availability.
- Obtain the information necessary for design improvement of those items whose inherent reliability proves inadequate.
- Accomplish these goals at a minimum total life cycle cost, including maintenance costs and the costs of residual failures.
- Obtain the information necessary for establishing a dynamic maintenance program that improves upon the initial program, and its revisions, by systematically assessing the effectiveness of previously defined maintenance tasks. Monitoring the condition of specific safety, critical, or costly components would play an important role in the development of a dynamic program.

These objectives recognize that maintenance programs, as such, cannot correct deficiencies in the inherent safety and reliability levels of the equipment and structures. The maintenance program can only minimize deterioration and restore the item to its inherent levels. If the inherent levels are found to be unsatisfactory, design modification or operational or procedural changes (such as training programs) may be necessary to obtain improvement.

Maintenance responsibility as Program Content

The content of the maintenance program itself consists of two groups of tasks.

One group is preventive maintenance tasks, which include failure-finding tasks, scheduled to be accomplished at specified intervals, or which are based on condition. The objective of these tasks is to identify and prevent deterioration below inherent safety and reliability levels by one or more of the following means:

- Lubrication or servicing
- Operational, visual, or automated check
- Inspection, functional test, or condition monitoring
- Restoration and Discard or disposal

It second group of tasks, which is determined by reliability-centered management (RCM) analysis, for example, it comprises the RCM-based preventive maintenance program.

- The other group includes nonscheduled maintenance tasks which result from
- Findings from the scheduled tasks accomplished at specified intervals of time or usage
- Reports of malfunctions or indications of impending failure (including automated detection)

The objective of this second group of tasks is to maintain or restore the equipment to an acceptable condition in which it can perform its required function. An effective program is one that schedules only those tasks necessary to meet the stated objectives. It does not schedule additional tasks that will increase maintenance costs without a corresponding increase in protection of the inherent level of reliability. Experience has clearly demonstrated that reliability decreases when inappropriate or unnecessary maintenance tasks are performed, due to increased incidence of maintainer-induced faults.

Responsibility for Safety

Safety is one of the most important aspects of industrial management today. The maintenance department should play a large part in making its plant a safe one in which to work.

- General administration of the safety effort is delegated to a specialist group, the maintenance department is often the key to success of the program. Not only is it responsible for the safety of its own personnel.
- It also is responsible for providing mechanical safeguards and for maintaining equipment and services in safe operating condition. Because of this collateral responsibility, the safety function combines with maintenance in a small plant.
- mechanical guarding and safe operating conditions are maintained in the shops, most of the work performed outside the shop is of a non repetitive nature, frequently requiring operation of equipment with guards or other safety devices removed.
- During repair of equipment in production areas, maintenance personnel must be continuously alert to the hazards they may be creating for themselves and less experienced personnel in the immediate area.
- Fire permits, lockout procedures, and warning signs must be used in this connection. Possibility of tools or pieces of equipment falling and injuring others is always present. Protection must be provided from exposure to welding, sandblasting, and oil spillage.

- Electrical work is always accompanied by potential hazards and deserves special attention.
- Safety in maintenance department activity, therefore, depends largely on the individual safety performance of its men. In a production department special in welding where obvious hazards are kept guarded and personnel instructed in performing a routine operation, programs and specific safety instructions are most effective.
- Standards for guards, grounding, bumping- and tripping-hazard elimination, warning signals, and safety devices must be closely followed. Installations of this type must be maintained in perfect operating condition. Often the actual inspection of safety devices rests with the maintenance department. Where this inspection is a function of the safety department or production department, close liaison must be maintained with maintenance for the immediate correction of deficiencies.

In conclusion, while the responsibility of staff's safety may be part of the maintenance function in a small workshop, usually it is preferable to have an independent safety department either reporting to top management or incorporated in the personnel department.

Regardless of its staff responsibility for safety, the maintenance department in any plant has a direct responsibility for implementation of the safety program, and its supervision must recognize this and provide the means for its accomplishment.

Responsibility as per Instrumentation aspects

The question of responsibility of the maintenance expert for instruments can best be answered by practical consideration of the problems peculiar to the plant involved. Instrument installation and maintenance theoretically should be considered in the same light as the addition of any other equipment.

In a workshop using relatively simple types of instruments their selection and maintenance is frequently a function of the electrical group. On the other hand, in some industries where instrumentation has been carried much further and includes knowledge of complex electronic components, particularly in fields of automation, instrumentation may be a separate plant department. In some industries, instruments are the major tools of production personnel and smooth operation requires their intimate knowledge of the instruments involved. In this situation, except for major changes, the responsibility for instrument care is with the production department.

With the increased use and complexity of instruments, the problem of providing trained personnel for selection and maintenance has also increased.

Technical men must frequently be used in a maintenance capacity for effective service. Unless there are enough instruments to warrant staffing the maintenance department with this caliber of personnel, the responsibility may be best transferred to those technical personnel operating the plant.

Responsibility As Communications aspect

Generally, all communications should be reduced to a minimum consistent with effective operation. It is also accepted that information should flow upward only as far as is necessary for effective action.

Slower response frequently invalidates the value of higher-level judgment that might result from a flow of the information upward beyond this point. In addition, communication upward should be so handled that each level passes on only that information which is of *value* to the next level. Horizontal channels of communication should also be controlled to limit information to that necessary for effective cooperation between various sections of the maintenance group. In a small plant having only two or three levels between first-line supervision and the department head, and where most transactions can be handled by telephone or word of mouth, there is little problem. As the plant gets larger, with more intermediate levels of supervision, more procedural formality and greater specialization of duties develop

Management Responsibility

In order to establish a workshop wide lubrication program, management should arrange to have a survey conducted on each piece of equipment, noting the manufacturer's recommendations and warranty provisions for lubrication along with machine condition, operating speeds and loads, operating conditions (such as contaminants and temperatures), and machine history. This information can be computerized to establish lubrication/maintenance schedules, oil change intervals, and routes to perform the actual lubrication tasks.

A general inspection of equipment should be made once a month. At every third month, the plant superintendent or chief engineer should invite an engineer from the lubricant supplier to accompany maintenance personnel on their inspection tour. By working together, they can determine where the use of an improved type of bearing or lubricating device would make a machine run more smoothly, longer, and more economically, where a more suitable grade of lubricant would reduce the frequency of lubrication, or where the housing of overexposed gears would improve safety and reduce fire hazards. Management can promote preventive maintenance by praising operators personally for keeping their machines and working areas clean of dirt and oil. The spoken words "well done" are often much more appreciated than an impersonal memo from the front office with the same message.

Table 2.1. Duties of Lubrication Personnel

1	Use correct lubricants in every case and as few types as possible for the plant as a whole.
2	Apply lubricants properly.
3	Apply the correct amount of lubricant.
4	Apply lubricants at proper intervals.
5	Develop schedules for items 1 to 4 for each machine, distribute or post them, and see that they are followed
6	Train and instruct the oilers, and arrange for lubrication clinics if the number of oilers warrants. Suppliers' sales and engineering representatives frequently can render valuable assistance in the preparation and execution of such programs.
7	Install and use lubricating devices correctly.
8	Keep lubricants clean by keeping the oil room clean and keeping lubricant containers covered.
9	Dispense lubricants through clean, properly identified equipment.
10	Practice preventive maintenance.
11	Cooperate with the maintenance and production departments on lubrication problems.
12	Collect used oils for purification for resale or reclamation if quantity warrants.
13	Keep complete consumption records.
14	Record and analyze all lubrication-connected failures and breakdowns.
15	Eliminate all accident hazards connected with lubrication.
16	Keep abreast of new developments and practices in the lubricating field by periodic consultation with a qualified lubrication engineer—staff, consultant, or supplier's representative.
17	Minimize the total cost of lubrication, remembering that the price of an improper lubricant is a small fraction of its final cost in terms of poor service.

Responsibilities as per Employee

- Lubrication supervisors, oilers, and operators have the greatest responsibilities involving lubrication.
- Lubrication personnel have to be properly trained on storage, handling, application, and use of lubricants.
- Safety of operating personnel also must be considered. Usually it is practical to plan for inclusion and installation of modern systems of lubrication so that operators will not be exposed to hazards when adjusting fittings or going through normal re-lubrication procedures.
- complicated parts that require hand lubrication can involve personal hazard, especially if this is done while the machine is in operation. The designer should work to prevent such hazards by putting intricate parts on centralized systems, even though it may require external service lines from the main oil or grease supply.
- They must then perform the lubrication tasks in accordance with the recommended lubrication schedules. That are provides a list of lubrication duties that is reproduced in Table 1.1.

2.2. Defects and Functionality of tools and equipment

2.2.1. Functions, Failures, and Faults

A. **Function:** The primary (essential) functions of several engineered objects. There are many other functions for an object, and the elements are as indicated below in the context of a power plant:

- **Essential function:** This defines the intended or primary function. In the case of a thermal power plant, it is to provide electrical power on demand to the consumers who are part of the network.
- **Auxiliary functions:** These are required to support the primary function. They are usually less clear than essential functions. For example, "preserving fluid integrity" is an auxiliary function of a pump and its failure may cause a critical safety hazard if the fluid is toxic or corrosive.
- **Protective functions:** The two-fold goal here is to protect people from injury and protect against damage to the environment. Examples of these are relays that offer protection against current surges and scrubbers on smokestacks that remove particulate matter to protect the environment.
- **Information functions:** These comprise condition monitoring, gauges, alarms, and so on. In a power plant, the main control panel displays various bits of information about the different subsystems – for example, voltage and current output of generators, pressure and temperature of steam in the various parts of the plant, and so on.

B. **Failures:** *Failure* is the termination of the ability of an item to perform a required function. A system failure occurs due to the failure of one or more of its components. Propose the following classification for failures:

- **Primary failure:** A primary failure of a component occurs when the component fails due to natural causes (for example, aging). An action (for example, repair or replacement by a working unit) is needed to make the component operational.
- **Secondary failure:** A secondary failure is the failure of a component due to one or more of the following causes*:* the (primary) failure of some other component(s) in the system, (ii) environmental factors, and/or (iii) actions of the user.
- **Command failure:** A command failure occurs when a component is in the non-working (rather than a failed) state because of improper control signals or noise (for example, a

faulty action of a logic controller switching off a pump). Often, no corrective action is needed to restore the component to its working state in this case.

C. Faults: A *fault* is the state of an item characterized by its inability to perform its required function.

Note that this excludes situations arising from preventive maintenance or any other intentional shutdown period during which the system is unable to perform its required function. A fault is, hence, a state resulting from a failure.

D. Failure Modes is a description of a fault It is sometimes referred to as a fault mode. Failure modes are identified by studying the (performance) function of the item. a classification scheme for failure modes:

- **Intermittent failures***:* Failures that last for only a short time. A good example of this is a software fault which occurs only under certain conditions that occur intermittently.
- **Extended failures:** Failures that continue until some corrective action rectifies the failure. They can be divided into the following two categories:

  Complete failures: Failures which result in a total loss of function.

  Partial failures: Failures which result in a partial loss of function.

Each of these can be further subdivided into the following:

Sudden failures: Failures that occur without any warning.

Gradual failures: Failures that occur with signals to warn of the occurrence of a failure.

A complete and sudden failure is called a *catastrophic* failure and a gradual and partial failure is designated a *degraded* failure.

E. Failure Causes and Severity: Failure cause is the circumstances during design, manufacture, or use which have led to a failure

The failure cause is useful information in the prevention of failures or their reoccurrence. Failure causes may be classified as indicated below:

- ***Design failure:*** Due to inadequate design;
- ***Weakness failure:*** Due to weakness (inherent or induced) in the system so that the system cannot stand the stress it encounters in its normal environment;
- ***Manufacturing failure:*** Due to non-conformity during manufacturing;
- ***Aging failure:*** Due to the effects of age and/or usage;

- ***Misuse failure:*** Due to misuse of the system (operating in environments for which it was not designed);
- ***Mishandling failure:*** Due to incorrect handling and/or lack of care and maintenance.

The *severity* of a failure mode signifies the impact of the failure mode on the system as a whole and on the outside environment. A severity ranking classification scheme is as follows:

- ***Catastrophic:*** Failures that result in death or total system loss;
- ***Critical:*** Failures that result in severe injury or major system damage;
- **Marginal:** Failures that result in minor injury or minor system damage;
- ***Negligible:*** Failures that result in less than minor injury or system damage.

2.2.2. Linking welding equipment and Component Failures

Equipment is a collection of interconnected components. The failure of tools is due to the failure of one or more of the components of the equipment. The linking of component failures to equipment failures can be done using two different approaches. The first is referred to as the forward (or bottom-up) approach and the second as the backward (top-down) approach.

In the forward approach, one starts with failure events at the component level and then proceeds forward to the equipment level to evaluate the consequences of such failures on equipment performance. ***Failure modes and effects analysis*** **(*FMEA*)** uses this approach.

In the backward approach, one starts at the equipment level and then proceeds downward to the part level to link system performance to failures at the part level. ***Fault tree analysis*** **(*FTA*)** uses this approach.

Failure Modes and Effects Analysis

FMEA is a structured, logical, and systematic approach. FMEA involves reviewing a system in terms of its subsystems, assemblies, and so on, down to the component level, to identify failure modes and causes and the effects of such failures on a system's function. The exercise of identifying component failure modes and determining their effects on the system function assists the design engineer/analyst in developing a deeper understanding of the relationships among the system components. The analyst can then use this knowledge to suggest changes to the system that can eliminate or mitigate the undesirable consequences of a failure. FMEA is used to assess system safety and to identify design modifications and corrective actions needed to mitigate the effects of a failure on the system

According to IEEE Standard 352, some of the objectives of FMEA are as follows:

- To ensure that all conceivable failure modes and their effects on operational success of the equipment have been considered;
- To list potential failures and identify the magnitude of their effects;
- To ensure that all conceivable failure modes and their effects on operational success of the equipment have been considered;
- To list potential failures and identify the magnitude of their effects;
- To provide historical documentation for future reference to aid in the analysis of field failures and consideration of design changes;
- To provide a basis for establishing corrective action priorities;
- To assist in the objective evaluation of design requirements related to redundancy, failure detection systems, fail-safe characteristics, and automatic and manual override.

FMEA Procedure

The FMEA methodology is based on a hierarchical, inductive approach to analysis; the analyst must determine how every possible failure mode of every system component affects the system operation. The basic procedure consists of:

1) Determining the item functions;
2) Identifying all item failure modes – usually these are the ways in which the item fails to perform its functions;
3) Determining the effect of the failure for each failure mode, both on the component and on the overall system being analyzed;
4) Classifying the failure by its effects on the system operation and mission;
5) Determining the failure's probability of occurrence;
6) Identifying how the failure mode can be detected (this is especially important for fault-tolerant configurations);
7) Identifying any design changes to eliminate the failure mode, or if that is not possible, mitigate or compensate for its effects.

The details of the FMEA analysis are documented on special worksheets. Figure 2.8 is an example which indicates the format to describe the failure modes and their consequences.

Table 2.2. Failure Mode and Effect analysis worksheet.

Component	Function	Failure mode	Failure cause	Failure effects	
				Component	Equipment

Fault Tree Analysis

FTA is concerned with the identification and analysis of conditions and factors that cause, or may potentially cause or contribute to, the occurrence of a defined *top event* (such as failure of a system). A fault tree is an organized graphical representation of the conditions or other factors causing or contributing to the occurrence of the top event. FTA can be used for analysis of systems with complex interactions between the components, including software–hardware interactions.

FTA is a deductive (top-down) method of analysis aimed at pinpointing the causes or combinations of causes that can lead to the defined top event. The analysis can be qualitative or quantitative, depending on the scope of the analysis.

FTA may be undertaken independently of, or in conjunction with, other reliability analyses and its objectives include:

- Identification of the causes or combinations of causes leading to the top event;
- Determination of whether a particular system reliability measure meets a stated requirement;
- Determination of which potential failure mode(s) or factor(s) would be the highest contributor to the system probability of failure (unreliability) or unavailability, when a system is repairable, for identifying possible system reliability improvements; and
- Analysis and comparison of various design alternatives to improve system reliability.

It is important to understand that a fault tree is tailored to its top event. Therefore, the fault tree includes only those faults that contribute to this particular top event. Moreover, the generated faults are not exhaustive – they contain only the faults that are deemed to be realistic by the design engineer/analyst.

2.2.3. Replacement

This strategy is to replace the equipment instead of performing maintenance. It could be a planned replacement or replacement upon failure.

Each of the maintenance strategies described above has a role to play in the plant operation. It is the optimal mix of these maintenance strategies that results in the most effective maintenance philosophy. The size of the plant and its planned level of operation coupled with the applicable maintenance strategy can assist in estimating the maintenance load or the desired output of the maintenance system. Figure 1.3 summarizes the maintenance strategies and for more on maintenance

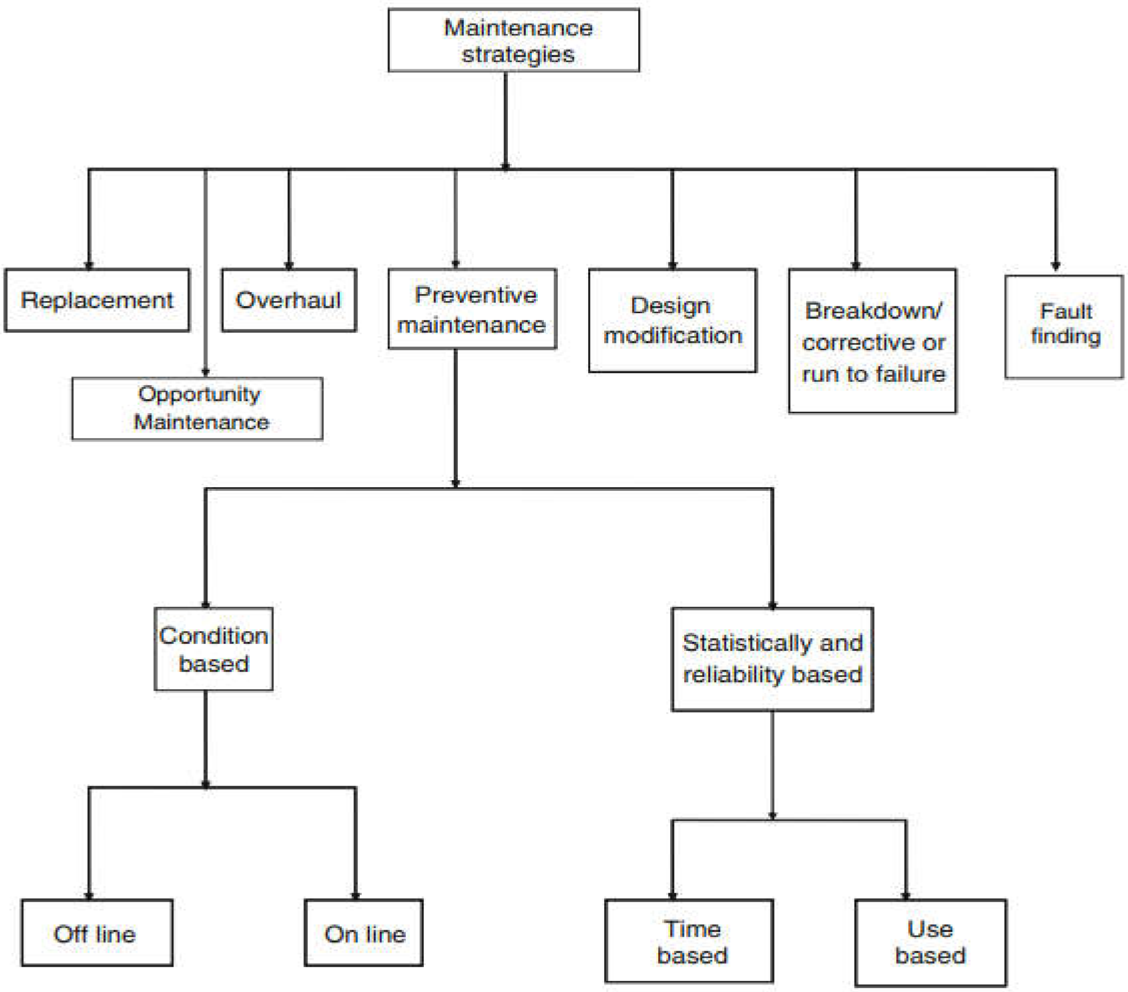

Figure 2.2. Maintenance strategies

2.3. Documentation of defective hand tools and equipment

2.3.1. Reasons for Data Collection

Defective data can be collected from hand tools and equipment or from the field. In either case a formal failure-reporting document is necessary in order to ensure that the feedback is both reliable and adequate. Field information is far more valuable since it concerns failures and repair actions that have taken place under real operating conditions. Since recording field incidents relies on people, it is subject to errors, omissions and misinterpretation. It is therefore important to collect all field data using a formal document. Information of this type has a number of uses, the main two being feedback, resulting in alteration to prevent further defects and the acquisition of statistical reliability and repair data. In detail, then, they:

- Indicate design and manufacture deficiencies and can be used to support reliability growth programs (Section 12.3)
- Provide quality and reliability trends
- Identify wearout and decreasing failure rates
- Provide subcontractor ratings
- Contribute statistical data for future reliability and repair time predictions
- Assist second-line maintenance (workshop)
- Enable spares provisioning to be refined
- Allow routine maintenance intervals to be revised
- Enable the field element of quality costs to be identified.

A failure-reporting system should be established for every workshop, equipment and tools. Customer cooperation with a reporting system is essential if feedback from the field is required and this could well be sought, at the contract stage, in return for some other concession.

2.3.2. Record Information and Defectives

A failure report form must collect information covering the following:

- Repair time – active and passive
- Type of fault – primary or secondary, random or induced, etc.
- Nature of fault – open or short circuit, drift condition, wearout, design deficiency
- Fault location – exact position and detail of LRA or component
- Environmental conditions – where these are variable, record conditions at time of fault if possible

- Action taken – exact nature of replacement or repair
- Personnel involved
- Equipment and Spares used
- Unit running time (from installation until the failure).

The main problems associated with failure recording are:

A) Inventories
B) Motivation
C) Verification
D) Cost
E) Recording non-failures
F) Times to failure:.

2.3.3. Spreadsheets and Databases of defectives

Many data-collection schemes arrange for the data to be manually transferred from the written form into a computer. In order to facilitate data sorting and analysis it is very useful if the information can be in a coded form. This requires some form of codes database for the field maintenance personnel in order that the various entries can be made by means of simple alpha numeric's. This has the advantage that field reports are more likely to be complete since there is a code available for each box on the form. Furthermore, the codes then provide definitive classifications for subsequent sorting. Headings include:

Table 2.3. details field of Spreadsheets and Databases of defectives

Equipment code Preferably a hierarchical coding scheme that defines the plant, subsystem and item as, for example, RC1-66-03-5555, where:

Code	**Meaning**
R	Bahir dar plant
C1	Shear system
66	Power generation
03	Switchgear
5555	Actual item

How found: The reason for the defect being discovered as, say, a two-digit code:

Code	**Meaning**
01	Plant shutdown
02	Preventive maintenance
03	Operating problem

Type of fault: The failure mode, for example:

Code	Meaning
01	Short circuit
02	Open circuit
03	Leak
04	Drift
05	No fault found
etc.	

Action taken Examples are:

Code	Meaning
01	Item replaced
02	Adjusted
03	Item repaired
etc.	

Discipline

Where more than one type of maintenance skill is used, as is often the case on big sites, it is desirable to record the maintenance discipline involved. These are useful data for future maintenance planning and costing. Thus:

Code	Meaning
01	Electrical
02	Instrument
03	Mechanical
etc.	

Free text: In addition to the coded report there needs to be some provision for free text in order to amplify the data.

Each of the above fields may run to several dozen codes, which would be issued to the field maintenance personnel as a handbook. Two suitable types of package for analysis of the data are *spreadsheets* and *databases*. If the data can be inputted directly into one of these packages, so much the better. In some cases the data are resident in a more wide-ranging, field-specific, computerized maintenance system. In those cases it will be worth writing a download program to copy the defect data into one of the above types of package.

Spreadsheets such as Lotus 1-2-3 and Excel allow the data, including text, to be placed in cells arranged in rows and columns. Sorting is available as well as mathematical manipulation of the data.

In some cases the quantity of data may be such that spreadsheet manipulation becomes slow and cumbersome, or is limited by the extent of the PC memory. The use of *database* packages permits more data to be handled and more flexible and fast sorting. Sorting is far more flexible than with spreadsheets since words within text, within headings or even 'sound-alike'

2.3.4. Best documentation Practice

The following list summarizes the best practice together with recommended enhancements for both manual and computer based field failure recording. Recorded field information is frequently inadequate and it is necessary to emphasize that failure data must contain sufficient information to enable precise failures to be identified and failure distributions to be identified. They must, therefore, include:

(a). Adequate information about the symptoms and causes of failure. This is important because predictions are only meaningful when a system level failure is precisely defined. Thus component failures that contribute to a defined system failure can only be identified if the failure modes are accurately recorded. There needs to be a distinction between failures (which cause loss of system function) and defects (which may only cause degradation of function).

(b). Detailed and accurate equipment inventories enabling each component item to be separately identified. This is essential in providing cumulative operating times for the calculation of assumed constant failure rates and also for obtaining individual calendar times (or operating times or cycles) to each mode of failure and for each component item. These individual times to failure are necessary if failure distributions are to be analyzed by the Weibull method

(c). Identification of common cause failures by requiring the inspection of redundant units to ascertain if failures have occurred in both (or all) units. This will provide data to enhance models In order to achieve this it is necessary to be able to identify that two or more failures are related to specific field items in a redundant configuration. It is therefore important that each recorded failure also identifies which specific item (i.e. tag number) it refers to.

(d). Intervals between common cause failures. Because common cause failures do not necessarily occur at precisely the same instant it is desirable to be able to identify the time elapsed between them.

(e). The effect that a ‘component part’ level failure has on failure at the system level. This will vary according to the type of system, the level of redundancy (which may postpone system level failure), etc.

(f). Costs of failure, such as the penalty cost of system outage (e.g. loss of production) and the cost of corrective repair effort and associated spares and other maintenance costs.

(g). The consequences in the case of safety-related failures (e.g. death, injury, environmental damage), which are not so easily quantified.

(h). Consideration of whether a failure is intrinsic to the item in question or was caused by an external factor. External factors might include: process operator error induced failure maintenance error induced failure caused by a diagnostic replacement attempt modification induced failure.

(i). Effective data screening to identify and correct errors and to ensure consistency. There is a cost issue here in that effective data screening requires significant man-hours to study the field failure returns. In the author’s experience an average of as much as one hour per field return can be needed to enquire into the nature of a given failure and to discuss and establish the underlying cause. Both codification and narrative are helpful to the analyst and, whilst each has its own merits, a combination is required in practice. Modern computerized maintenance management systems offer possibilities for classification and odification of failure modes and causes. However, this relies on motivated and trained field technicians to input accurate and complete data. The option to add narrative should always be available.

(j). Adequate information about the environment (e.g. weather in the case of unprotected equipment) and operating conditions (e.g. unusual production throughput loadings)

2.4. Lubrication on tools and equipment

2.4.1. Fluid Management

Fluid management programs are being used in many plants to extend lubricant life and reduce disposal costs. There are four essential components in a fluid management program: selection of the lubricant, lubricant monitoring during use, lubricant maintenance using processing and refortification techniques, and finally, disposal of the spent lubricant.

Lubricant Selection

Fluid management begins with selecting the correct lubricant for the application. For most equipment, premium long-lasting lubricants meeting equipment manufacturers' recommendations and specifications should be selected

On the other hand, purchase of premium-grade lubricants will not improve or correct lubrication problems if mechanical factors such as misalignment or severe environments (high levels of dirt and water contaminants) are involved.

Lubricant Monitoring Programs

monitoring programs may be used to determine the condition of the lubricant and to detect early signs of equipment failure. Used oil analyses also can be used to extend lubricant life and establish oil change out intervals. The properties that should be monitored are dependent on the application and environment. Table 1.2 lists the properties and condemning limits for most large-volume applications of industrial lubricants, namely, turbine/circulating, hydraulic, compressors, and gear oils.

Other lubricant applications, such as slideways, rock drills, and so on, which involve small volumes and/or once-through applications, need no monitoring. The results of monitoring tests can be used in some cases to correct conditions that are contributing to degradation of the lubricant. For example, if the lubricant in a circulating system shows that water is present, it may be possible to locate and eliminate the source of the water. If the viscosity is dropping, it may be determined that incorrect oil is being used for makeup, or there may be leakage of a different lubricant into the system. The critical limits shown in the table are intended to serve as general guidelines. The lubricant supplier should provide actual limits for the products being used and interpretation of used oil test results.

Lubricant Maintenance

Lubricant maintenance is closely associated with the monitoring program. When used oil test results exceed the critical limits, corrective action needs to be taken. Such action could include filtration to remove particulate matter and in some cases oxidation products and/or dehydration. This processing can be done either on site or at a recycle station. Additive replenishment for depleted

Table 2.4. Critical Limits For Used Oils

	Turbine/circulating	Hydraulic	Compressor	Gears
Appearance	Hazy or cloudy indicates moisture or fine particulate matter present. Recondition by filtration, centrifugation, and/or dehydration.			
Water content	If moisture content exceeds 0.1 percent, treat as above or change out. Locate and eliminate the water source.			
Neutralization no.	Change of 0.2 above original is cause for concern. Change of 0.5 requires recycle or replacement.			
Viscosity	Change of 10 % indicates action required. If change is due to oxidation, change or recondition oil; if due to addition of incorrect viscosity grade, correct by addition of appropriate grade.		Change of 25 percent indicates that corrective action is needed, as indicated for turbine oils.	
Flash point	Not usually run unless contamination is suspected (low viscosity or smell). Above 375°F, no action is required. If below, contamination is indicated. Action indicated above should be initiated			
Particle count	SAE class 6 max	SAE class 3 max	SAE class 6 max	Generally not applicable
Rust test (D665A)	If failing, change oil or reinhibit			Generally not applicable
Sediment	If not visually clear, recondition by filtration/centrifugation.			
Oxidation stability RBOT,minutes	If less than 50, change oil or reinhibit	Generally not applicable	Same as turbine oil	Generally no

Inhibitors may be feasible for some products in some applications. Since additive replenishment requires a considerable amount of technical expertise, the lubricant supplier should be contacted to provide information and service to reclaim and refortify used lubricants.

Disposal

Disposal is the last step that must be addressed in fluid management when the monitoring results indicate that the oil is severely degraded and/or depleted of additives that cannot be restored. Various options to consider include recycling, burning, land-filling, and re-refining. The most appropriate method of disposal will depend on local, state, and federal regulations. These will clearly be affected by the location, which makes the best method of disposal site-specific. Lubricant disposal needs to be considered carefully on a case-by-case basis.

2.4.2. Lubricant Protection

Proper handling and storage of lubricants and greases are important to ensure longevity and satisfactory performance. Premium-grade products should be stored inside to prevent contamination with dirt and water and to protect against temperature extremes. If drums are stored outside, they should be stored on their sides, tilted, or upside down. Drums will expand and contract as the temperature changes and any water on top of a drum may be drawn through the bung as the drum expands and contracts. Ester- and polyglycol-based lubricants need especially to be protected from atmospheric humidity.

Location and Personnel

A clean, well-lighted room or building is advisable, with provisions for heating in cold weather. It should be specifically kept for lubricant storage and reserve lubricating equipment. In most plants, one or two individuals are assigned the responsibility for inventory and dispensing of lubricants. These individuals should be trained on the importance of protecting lubricants from contamination and commingling with other lubricants. Drums should be labeled clearly to ensure application/use of the correct lubricant.

Facilities for Handling Containers

One-level handling is an important item wherever possible in planning for lubricant storage. If practical, the floor level should be the same as the delivery-truck floor. Grease drums are normally stored on end because the contents are removed by paddle, scoop, or pressure pump, according to the consistency of the grease. Paddles, scoops, and other devices must be kept clean to protect against abrasive particles and dirt.

Lighting

The lubrication and maintenance departments can function most effectively when they have complete records as to lubricant consumption per machine per area. This requires careful inventory (monthly) and recording of amounts of oil and grease issued. Lighting plays an important part. If the storeroom is painted gloss white, if light outlets are well located to obviate glare, and if a comfortable record desk is installed, personnel will keep more careful records.

Fire Protection

The possibility of fire in a well-planned lubricant storage area is remote, assuming that no-smoking rules are observed, that casual visits from other plant personnel are prohibited, that oil drip is prevented or cleaned up promptly, that waste or wiping rags are stored in metal containers and in minimum quantity, and that sparking or arcing tools are used only under conditions of good ventilation. Even so, insurance regulations will require installation of suitable fire-extinguishing equipment and possibly a sprinkler system. The accepted foam-type device for smothering is best. In a small storeroom, one or two hand units may suffice. In a larger area, a multiple-gallon foam cart with adequate hose may be required.

2.4.3. Greases

Lubricating grease can be defined as a solid to semisolid material consisting of a thickening agent dispersed in a liquid lubricant. Because greases are semisolid materials, they can be used in applications where leakage of an oil will occur. Also, greases can provide a natural sealing action, as in a bearing application where the grease film tends to keep contaminants out and the oil film in. The thickener system used to form a grease also can provide an extra film thickness over that provided by a lubricating oil.

Components of Greases

Greases consist of three components:

1) a fluid lubricant, which usually makes up 70 to 95 wt% of the finished grease,
2) a thickener, which provides the gel-like consistency that holds the liquid lubricant in place and usually makes up from 3 to 15 wt% of the finished grease, and
3) Additives, which are added to enhance certain properties of the finished grease and usually make up from 0.5 to 10 wt% of the finished grease.

Each of these components must be selected and formulated in the proper proportion to obtain a grease with the desired performance properties. The fluid lubricant most often used is an oil derived from petroleum. Both paraffinic and naphthenic oils are used, and these can be either a single component or a blend. Synthetic-base oils also can be used, but owing to their higher cost, synthetic-base oils are usually used in specialty greases where extreme low-temperature or high-temperature performance characteristics are required. The thickener systems most often used to form greases are soaps such as those formed by the saponification of a fatty material with an alkali metal. These metallic soaps include sodium, calcium, lithium, and aluminum. In addition to soap thickeners, nonsoap chemical compounds such as those based on a urea derivative are also used, as well as inorganic materials such as those made from certain clays (i.e., montmorillonite). Additives, the third component of a grease, are used to modify and improve certain properties of the grease. The principal types of additives used are antioxidants, rust and corrosion inhibitors, extreme pressure/antiwear agents, tackifiers, and solid fillers. Antioxidants are used to protect the grease during extended storage and to extend the service life at elevated temperatures. Rust and corrosion inhibitors provide protection for rusting in the presence of water and inhibit the grease from attacking certain metals such as copper and bronze. Anti-wear agents function to extend the loads that can be carried by the lubricant film and reduce wear under boundary lubrication. Tackifiers are used to improve the resistance of the grease to water and to improve the adherence of the grease to a metal surface. Solid fillers are used to improve grease performance under conditions of extremely high loads, where metal-to-metal contact is highly likely.

Grease Properties and Tests

The single most distinguishing property of grease is its consistency, which is related to the hardness or softness of the grease. The consistency is related to the penetration number obtained on the grease and is defined as the depth, in tenths of a millimeter, that a standard cone penetrates a sample of grease under prescribed conditions of weight, time, and temperature. To ensure a uniform sample, the grease is “worked” 60 strokes in a prescribed manner before running the penetration test (ASTM D217).

Based on the worked penetration value, the National Lubricating Grease Institute (NLGI) has devised a classification system using defined consistency grades ranging from 000 (very soft) to 6 (very hard). Each consistency grade has a range of 30 penetration units, with a 15 penetration unit range between each grade. This classification system is shown in Table 1.3. As indicated in Table 1.3, a no. 2 grade grease will always have a worked penetration in the range of 265 to 295, as determined by the penetration test. Of the grades available, grades 0, 1, and 2 are the most widely used in industry. The more fluid grades, 00 and 000, are used when a thickened oil is desired, such as in the lubrication of gearboxes, where high leakage may occur when using a conventional oil lubricant.

Table 2.5. Classification of Greases according to NLGI

NLGI grade	Worked penetration range (tenths of a millimeter)
000	445–475
00	400–430
0	355–585
1	310–340
2	265–295
3	220–250
4	175–205
5	130–160
6	85–115

Another important property of a grease is its dropping point. Since greases are semisolid materials, they exhibit a characteristic temperature range wherein they change from a semisolid to a fluid.

Greases do not have a sharp melting point but, upon heating, become softer until at some point they become essentially fluid and no longer function as a thickened lubricant. Dropping points are useful in characterizing greases. Each type of soap thickener exhibits a particular dropping point range. Table 1.4 shows the typical dropping point ranges for greases containing different thickeners.

Greases cannot be used at temperatures above their dropping points. However, the dropping point by itself does not establish the maximum usable temperature. The maximum usable temperature is considered to be the temperature limit where the grease should not be used without frequent relubrication. As noted in Table 1.4, the maximum usable temperature is well below the dropping point of the grease. As a general rule, the maximum usable temperature of a grease should be at least 25 to 50°F below its dropping point. With frequent relubrication or continuous lubrication, the maximum usable temperature can be raised. Extended use at temperatures above 350°F usually will result in severe oxidation of the grease. For example, for an organo-clay grease, even though the thickener can withstand very high temperatures (above 500°F), the fluid lubricant component of the grease will be severely oxidized, leaving behind only the solid thickener, which has very poor lubrication properties. Once the fluidlubricant component is removed from the grease, the remaining thickener component becomes dry and abrasive. This is why frequent relubrication is required when operating a grease at high temperatures.

Other grease properties are also important when considering a particular grease for a specific application. These include resistance to softening (shear stability), oxidation resistance, water resistance, anti wear protection, corrosion and rust resistance, and pumpability. Table 1.5 lists tests that are used to characterize these properties.

Grease Thickeners

As noted earlier, greases can be classified by the type of thickener used, such as soap-thickened, complex soap–thickened, or non–soap-thickened greases. The characteristics and principal applications of the various types of greases are discussed in the following paragraphs.

Aluminum Soaps. Aluminum soaps are made by reacting aluminum hydroxide with a fatty acid, such as stearic acid. These finished greases are characterized by having a smooth, gel-like appearance, a low dropping point, good water resistance, and thixotropic behavior (softening or hardening dependent on shearing rate). Aluminum greases were used on slow-speed bearings under wet conditions; however, use of this type of grease has greatly decreased in favor of the higher–dropping-point complex analogues.

Sodium Soaps. Sodium soaps are made by reacting sodium hydroxide with a tallow-derived triglyceride or fatty acid. The finished grease is characterized by having a rough, fibrous appearance, a moderately high dropping point, good adhesive (cohesive) properties, but very poor water resistance. Sodium greases are used widely in certain plain, slow-speed bearings and in gearboxes where water contact is low. These greases should never be used in applications with any appreciable exposure to water.

Table 2.6. Dropping Point and Maximum Usable Temperature of Greases

Thickener type	Dropping point range, °F	Maximum usable temperature, °F
Calcium, water-stabilized	210–220	175
Aluminum	220–230	175
Calcium, anhydrous	275–285	250
Sodium	340–350	250
Lithium	385–395	325
Complex soap	Above 450	350–400
Non-soap poly urea	Above 450	350–400
Non-soap organo clay		

Table 2.7. Tests for Characterizing Greases

Property	Test
Shear stability	Multi stroke penetration Shell roll Wheel bearing leakage
Oxidation resistance	Bomb oxidation Bearing life tests Pressure difference scanning calorimetry
Water resistance	Water washout Water spray-off Water absorption
Oil bleed resistance	Oil bleed tests Pressure oil separation
EP/antiwear	Four-ball wear and EP Timken SRV wear test Fafnir
Corrosion/rust	Rust test Emcor rust test Copper corrosion
Pumpability	USS mobility Apparent viscosity Low-temperature torque tests

Compatibility of Greases

Because there are so many different types of thickeners used to manufacture greases, the mixing of various types of greases occurs quite often in the field. Grease compatibility is a question that is often raised in the field when one grease is being replaced with another. If two greases are incompatible, serious problems could occur.

A definition of *incompatibility* is as follows: "Two lubricating greases show in compatibility when a mixture of the products shows physical properties and service performance which are markedly inferior to those of either of the greases before mixing."

Generally, laboratory testing is required to determine if two greases are compatible. If laboratory tests indicate a compatibility problem, it is usually recommended that the greases not be mixed in service. When changing from one type of grease to another, the piece of equipment should be cleaned of the old grease, or if that is not possible, then the old grease should be flushed from the system by the new grease. Frequent relubrication with the new grease should be followed for a period of time to be reasonably sure that all the old grease has been replaced.

2.4.4. Lubricating Devices and system

Good lubrication is simply placing the right amount of the right lubricant in the right place at the right time. There are many devices and systems available today to achieve this in a variety of environmental conditions and operating situations.

Manually and electrically powered grease guns are used in some remote locations. Canisters containing compressed air and thin-film/dry-film lubricants and solvents are available to manually apply the lubricant to slides and guides, corroded mechanisms, and frozen bearings to break them loose. Regardless of what system or device is selected to provide lubrication, it is important that a good maintenance and follow-up program be implemented to keep the equipment operating properly. Manual techniques used to apply lubricants have been improved from the old lever-handled grease gun to portable compressed air or electrically operated pail pumps with hoses, reels, applicator nozzles, and related equipment. Many plants that have adequate aisle space and ready access to equipment provide golf cart type vehicles for their lubricators with these devices and the required lubricants on-board.

Centralized Automatic Lubrication Systems

Centralized automatic lubrication systems can be readily justified for the following reasons.

Safety

1) No climbing around running machinery.
2) Safe lubrication of bearings usually inaccessible because of location, gas, fumes, or height (blast furnaces, overhead cranes, and so on).
3) No excess spillage around machines to cause slippery conditions.

More Efficient Lubrication

1) Lubricant is applied in small, carefully controlled, correct amounts more frequently.
2) No skipping or underlubrication of any bearing or surface.
3) No wasteful overlubrication, as with the old hand-applied methods.

Increased Productivity

1) Increased machine life.
2) Lubrication is done automatically, while machine is running.
3) Increased operating time through reduced downtime.

Reduced Operating Costs

1) Reduced maintenance labor costs.
2) Lower power costs—less friction.
3) Fewer man-hours required for lubrication.

Better Housekeeping. Lubrication points, machines, and surrounding area remain clean of excess lubricants.

2.4.5. Types of Automatic Lubrication Systems

Types of lubrication systems have changed dramatically in the last decade. With the advent of programmable microprocessor controllers, proximity switches, and temperature monitoring devices, it is now possible to precisely control and monitor lubrication systems.

Automatic lubrication systems generally fall into the following simply defined categories:

(a). Oil mist system
(b). Orifice-control system
(c). Injector system
(d). Series-progressive system
(e). Twin-line system
(f). Duoline system
(g). Pump-to-point system
(h). Zone-control system
(i). Ejection system
(j). Injection system

Each of these lubrication systems has its place in industry. They range in applications from machine tool, primary metals, automotive, agriculture, mining, textile, and food packaging and processing to the military and aerospace industries. Each system, however, has its own unique characteristics and specific requirements

2.4.6. Planning and implementing a good lubricating program

Nearly all moving mechanical components of operating equipment roll or slide against other surfaces. If not properly lubricated, these surfaces can wear rapidly and require excessive amounts of energy. Many equipment malfunctions, repair costs, and resulting downtime can be traced—either directly or indirectly—to inadequate or improper lubrication.

The typical industrial environment contains silica dust, oxides, metal filings, and other abrasive materials. When these materials are mixed with some lubricants, they create a lapping compound that greatly accelerates wear. Unless proper lubricants and lubricating systems are utilized and proper procedures are followed to prevent contamination, premature equipment failure results. A well-planned and properly implemented lubrication program, designed to place the right amount of the right material in the right place at the right time, will more than pay for itself in reduced downtime, lower maintenance costs in both parts and labor, and reduced energy costs.

The multitude of lubricants recommended by equipment manufacturers can be simplified by selecting good multipurpose lubricants to reduce inventory requirements and the possibility of misapplication.

2.4.7. Components of Planning and Implementing the Lubrication Program

The activities to achieve and carry out an effective lubrication program are outlined in this segment. They consist of the plant lubrication survey, establishment of lubrication schedules and improvement in the selection and applications of lubricants, lubricant analysis, fluids management and quality assurance, activities required to implement the programs, and factors to consider if a single supplier source is desired for all plant lubricants. The program implement or should work closely with plant personnel to determine information now available and programs and procedures presently being used

A. The Plant Lubrication Survey

1) Identify equipment and component parts requiring lubrication, the specific location of each machine, and the model, serial number, function, manufacturer, operating instructions, and limitations.

2) Obtain similar information for each subcomponent of the machine, such as drive motors, gears, couplings, and bearings.
3) Examine the lubricant recommendations made by the machine or parts manufacturer and supporting documentation for these selections.
4) Determine the lubricants currently used, including quantity, cost, and supply source.
5) List the schedules in effect for each lubrication point, including frequency, quantity applied, and sampling schedules. Provide similar information for all machine components.
6) Identify the nature of each lubrication point and whether circulating systems are fed from central storage tanks, individual machine sumps, or grease fittings and whether manual, semiautomatic, or automatic equipment is now being used. Operating characteristics, condition, and effectiveness of the lubrication systems encountered should be determined.
7) Make a detailed visual inspection of each machine and its components for indications of problems, such as leakage; excessive noise; high temperature; vibration; and loose, damaged, or missing parts.
8) Record information relating to the adequacy of the machine to perform its intended functions.

Note: An effective approach for conducting the initial lubrication survey is to start with the units of equipment that are critical to maintaining continuous production and work toward the less critical units. This approach will achieve the greatest results in the shortest time period. When surveying an individual machine, start at the power source and follow through each power train, identifying couplings, reducers, bearings, and wear surfaces.

B. Establishment of Lubrication Schedules and Improvements in Selection and Application of Lubricants

1) Review current lubrication schedules, including type and amount of lubricant used and frequency of application.
2) Determine if it is the best lubricant for the specific application commensurate with the proposed lubricant product reduction program and improved performance requirements.
3) Analyze each piece of equipment to determine if the present lubrication system is adequate and if the lubrication points or central reservoirs are readily accessible.
4) Investigate opportunities to replace inadequate systems, manual systems, and malfunctioning automatic systems with state-of-the-art automatic systems that can be

justified through reduced labor, increased equipment reliability, and/or reduced energy costs.

5) Analyze operating records such as frequency of scheduled and unscheduled downtime and reason for each shutdown when preparing the new lubrication schedule.
6) Establish lubrication schedules and routings to minimize travel time and interference with production operations. Determine time required to perform specific lubrication functions and number of workers required to perform the job.
7) Establish a check-off or feedback procedure to indicate that the scheduled lubrication was accomplished with the proper lubricant.
8) Record and report the amount and type of lubricant consumed in each area and on major pieces of equipment.
9) New equipment lubrication specifications are to be determined prior to installation of the equipment.
10) Place tags at each fill point that calls out lubricant to be used, amount of lubricant, and lubrication schedule.

C. Lubricant Analysis

1) Establish the objectives of the analysis program, that is, monitor and track wear and lubricant quality to detect problems caused by adhesion, friction, and corrosion before there is major component damage and to determine when lubricant should be filtered, replaced, and/or fortified with additives.
2) Select the plant equipment to be included in the analysis program. Equipment selection is usually based on the importance of the equipment to continuity of plant operations.
3) Determine the sampling frequencies for each component.
4) Design the testing packages to meet the selected objectives. Typical tests for gear reducer lubricants include Wear particle analysis—wear metals, contaminate metals, and additive metals Total solids percentage volume—contamination leaks or environmental conditions Viscosity—fluidity of the lubricant Infrared analysis—oxidation/nitration (general lube degradation) Neutralization number—reserve alkalinity (Total base number [TBN]) or total acidity (Total acid number [TAN]) A glossary of tests for lubrication and fuel analysis
5) Select a lubricant testing laboratory that can accurately test the parameters chosen and report the results in a comprehensive manner on a timely basis.

6) Determine the cost of the analysis program.
7) Develop the sampling procedures and modify equipment as necessary to extract representative samples while the equipment is in operation.
8) Establish sampling, testing, and reporting schedules.
9) Develop procedures and lines of communication to report results and to initiate actions dictated by the test results.
10) Establish a program review schedule.

Note: A close liaison should be maintained between the lubricant analysis program and other predictive maintenance activities.

D. Fluids Management and Quality Assurance

1) Establish handling, storing, dispensing, application, housekeeping, and safety practices. Table 3.2 is a lubricant handling checklist.
2) Obtain *material safety data sheets* on all lubricants in the plant.
3) Periodically inspect and test lubricant shipments to determine if they meet established quality standards. Table 3.3 shows typical tests for oil quality.
4) Prevent comingling of lubricants.
5) Discard contaminated and obsolete lubricants in an environmentally acceptable manner.
6) Record ammeter readings on drive motors to monitor the effectiveness of lubrication.

Table 2.8. Typical Tests for Oil Quality

Viscosity	⇒ *R*eflects the flow characteristics of an oil. The right viscosity is essential for good penetrability and protection. Viscosity is measured in Saybolt unit seconds (SUS) or centistokes (cSt). For example, a synthetic heavy weight oil for high-temperature applications up to 500°F has a viscosity of 335 c St at 40°C or 250 SUS at 210°F—about the weight of SAE 140 gear oil.
Viscosity index(VI)	⇒Indicates the effect temperature change has on the viscosity of an oil. A high VI, typically over 100, is generally recommended for high-temperature applications. Some synthetics offer a VI above 200.
Carbon residue test	⇒ Measures the amount of carbonaceous material left after evaporation and pyrolysis.The more residue, the more likely the oil will "coke" and leave deposits on the chains. Look for numbers less than 1 percent
Four-ball wear test	⇒ Uses a steel ball under load. It is rotated within well formed by three identical stationary balls. Wear is reported as the average scar diameter formed on the stationary balls. A small scar diameter (less than 0.50 mm) indicates excellent antiwear properties.
Falex wear test	⇒ Also known as the pin and vee block test. The lower the number, the better the wear protection. The number indicates the number of teeth on a ratchet that advances on the test apparatus as wear reduces the dimensions of a test pin rotating between the jaws of the two vee blocks.
Flash point	⇒ Determines the lowest temperature at which an oil gives off sufficient vapors to ignite but not continue burning when a flame is passed over the sample.
Pour point	⇒ The lowest temperature where the oil flows under test conditions. The rule of thumb is to select a pour point at least 20°F below the lowest operating or starting temperature
Rust* (ASTM D655) *rating	⇒ ndicates the relative rust protection of an oil. It is a pass/fail rating

2.4.8. Calibration and its Checking

Calibration is a special form of preventive maintenance whose objective is to keep measurement and control instruments within specified limits. A ‘‘standard’’ must be used to calibrate the equipment. Standards are derived from parameters established by the National Bureau of Standards (NBS). Secondary standards that have been manufactured to close tolerances and set against the primary standard are available through many test and calibration laboratories and often in industrial and university tool rooms and research labs. Ohmmeters are examples of equipment that should be calibrated at least once a year and before further use if subjected to sudden shock or stress.

The purpose of a calibration system is to provide for the prevention of tool inaccuracy through prompt detection of deficiencies and timely application of corrective action. Every organization should prepare a written description of its calibration system. This description should cover the measuring of test equipment and standards, including the following:

1) Establishment of realistic calibration intervals
2) List of all measurement standards
3) Established environmental conditions for calibration
4) Ensuring the use of calibration procedures for all equipment and standards
5) Coordinating the calibration system with all users
6) Ensuring that equipment is frequently checked by periodic system or cross-checks to detect damage, inoperative instruments, erratic readings, and other performance-degrading factors that cannot be anticipated or provided for by calibration intervals
7) Provide for timely and positive correction action
8) Establish decals, reject tags, and records for calibration labeling
9) Maintain formal records to ensure proper controls.

The checking interval may be in terms of time (hourly, weekly, and monthly) or based on amount of use (e.g., every 5,000 parts, or every lot). Adherence to the checking schedule makes or breaks the system. The interval should be based on stability, purpose, and degree of usage. If initial records indicate that the equipment remains within the required accuracy for successive calibrations, then the intervals may be lengthened. On the other hand, if equipment requires frequent adjustment or repair, the intervals should be shortened.

Any equipment that does not have specific calibration intervals should be

(1) examined at least every 6 months and (2) calibrated at intervals of no longer than 1 year.

Adjustments or assignment of calibration intervals should be done in such a way that a minimum of 95% of equipment or standards of the same type is within tolerance when submitted for regularly scheduled recalibration. In other words, if more than 5% of a particular type of equipment is out of tolerance at the end of 18

Maintenance Fundamentals its interval, then the interval should be reduced until less than 5% is defective when checked.

A record system should be kept on every instrument, including the following:

1) History of use
2) Accuracy
3) Present location
4) Calibration interval and when due
5) Calibration procedures and necessary controls
6) Actual values of latest calibration
7) History of maintenance and repairs.

Test equipment and measurement standards should be labeled to indicate the date of last calibration, by whom it was calibrated, and when the next calibration is due. When the size of the equipment limits the application of labels, an identifying code should be applied to reflect the serviceability and due date for next calibration. This provides a visual indication of the calibration serviceability status. Both the headquarters calibration organization and the instrument user should maintain a two-way check on calibration. A simple means of doing this is to have a small form for each instrument with a calendar of weeks or months (depending on the interval required) across the top that can be punched and noted to indicate the calibration due date.

Table 2.9. Lubricant Handling Checklists

	Yes	NO		Yes	NO
I. Storage A. Lubricant containers, in use, are stored in a heated, power-ventilated room. Drums are kept off the floor and are supported by a rack, platform, or blocks at least several inches high.			**III. Dispensing** A. Oldest lubricant is used first.		
			B. Lubricant which is suspect because of long storage is checked for condition before use.		
B. Inventory records include such details as quantity of each lubricant in stock, its location, and minimum order quantities.			C. Drum spigots are used for fast dispensing, quick cutoff, and to prevent dripping waste		
C. Drums stored outside (even for brief time) are under shelter or covered with tarpaulin or drum covers			D. Different brands, grades, and types of oil are not mixed in dispensing containers.		
D. Drums are stored on their sides with the two bungs aligned horizontally (rather than up and down) so they are backed by fluid that prevents air from entering through bung threads.			E. Dispensing cans are inspected regularly for proper functioning of plungers, spring-closed lids, etc.		
E. Lubricant storage room is separated from areas of contamination sources, i.e., metal particles, dust, and chemical fumes			F. Dispensing cans are checked regularly for cleanliness and freedom from contamination.		
F. Solvent drums are grounded to avoid fires caused by electrical charges.			G. Containers are kept tightly closed when not in use.		

	Yes	NO		Yes	NO
G. Storage area is accessible both to delivery vehicles and machines to be serviced. H. Provision is made for clean and orderly storage of rags, swabs, paddles, cleaning supplies, sample cans, and other lubrication accessories			H. When using open containers, oil is drawn from drums and bulk tanks only when it is ready to be used.		
I. A specific area is provided for each of the following:			I. Use of galvanized containers is avoided to prevent reaction with the zinc		
(1) Unopened containers and bulk tanks.			**IV. Safety** A. Dispensing equipment is not left unattended. This prevents personnel tripping and falling over it.		
(2) Opened containers from which lubricants are being drawn.					
(3) Lubrication accessories and spare parts.					
(4) Oil filtering equipment and supplies.			B. Spilled or leaking lubricants are removed from floors to prevent slipping.		
(5) Cleaning and storing of dispensing equipment.					
(6) Recordkeeping.			C. Drum slings are used instead of rope slings for lifting.		
(7) Empty returnable containers.					
(8) Expansion (if expected).					
J. Emulsifiable oils are protected at all times from extremes of temperature, both high and low.			D. Lubricant and solvent containers are not left in direct sunlight, in very hot areas, or where there are sparks because of possible spontaneous combustion.		

	Yes	NO		Yes	NO
K. Bulk storage tanks are used when possible to reduce cost, save space, and avoid contamination.			E. High-pressure grease guns are used with care to prevent accidents.		
L. Storeroom personnel are properly trained in storage techniques, inventory control, and preventing contamination.			F. Oily rags are put in tightly closed safety containers and disposed of regularly		
M. Containers and hoses are clearly marked to avoid misapplication of lubricants			G. Storage tank vents are kept open.		
II. Handling A. Drums are not dropped or bounced off freight cars, trucks, and racks. B. Metal drum slings and overhead drum hoists are used when drums are tiered.			H. Smoking in lubricant and solvent storage areas is prohibited. I. Where necessary, machines are properly shut down before lubricating.		
C. Usually, fork trucks and wheeled hoists are used for drum-handling. Drums manually handled are rolled rather than dragged to avoid damage.			J. Secure ladders are used to reach high lubrication points.		
D. All containers are filled under clean conditions.			K. Light oils and solvents are properly vented to prevent excessive inhaling of fumes by personnel		
E. Grease drums are emptied completely before discarding					

Activities Required to Implement the Lubrication Management Program

1) Establish lines of communication with plant personnel, and determine responsibilities for the following:
   (a). Ordering lubricants
   (b). Receiving, handling, storing, and disposing of lubricants
   (c). Dispensing and applying lubricants
   (d). Ordering equipment and aides to implement the program
   (e). Drawing lubricant samples for test
   (f). Processing test samples
   (g). Reviewing test results
   (h). Taking corrective action as dictated by test results
   (i). Housekeeping and safety practices related to the program
   (j). Reporting the status and results of the lubrication management program to plant management
2) Establish the cost of the program.
3) Assign a trained lubrication specialist to the plant full time to carry out the program as outlined.
4) Train plant personnel, as necessary, to participate in the program.
5) Maintain records, and provide reports as required by the program and plant management.

   Note: This activity will require a terminal on the plant or maintenance department's computer or a separate computer that is compatible with the plant's operating system.
6) Contact plant management to receive approval for recommendations to eliminate or replace presently used lubricants and equipment or to introduce new lubricants and equipment.

2.5. Preparation and ways of Maintenance reporting

Performance Management Reporting t is highly recommended that the maintenance organization develop a weekly report. This report must be reviewed on a regular basis. Weekly is suggested, and a ''best practice'' is to have an open-door review policy.

The other suggested forum for review of maintenance management performance information is at the weekly operational asset management meeting.

This is an ideal forum for integrating performance management information into the operational fabric of the organization.

The examples provided illustrate how different organizations developed different unique methods for reporting organizational performance indicators

Operation Sheet 1

Practical demonstration of performing preventive maintenance/repairs by replacing oils lubricants on the Hydraulic Press machine

Operation Title: - repair and replacement Hydraulic Press machine

Purpose: This activity will develop the skill, knowledge and attitude of the trainees to Maintaining the supplementary welding tools and Equipment operation using Hydraulic Press machine.

Method manually repairs Hydraulic Press machine.

Procedure or Step

1. Develop oil lubricant checklist (refering from Table 2.10)
2. Wear properly personal protective equipment (PE)
3. Use properly Tools, Materials, & equipment.
4. Disconnect electric from the source
5. Check that the oil tank, oil line and press piston part is well lubricated or not
6. Clean the surface of the body of the machine
7. Remove the damage or broken machine part
8. Replace or repair the new one
9. Check the operation of the manually operated
10. Check the Replace or repair parts work properly
11. Finalize over all about the machine

Operation Sheet 2

Practical demonstration of performing preventive repairs by replacing consumable spare like carbon brush on portable grinding machine

Operation Title: - repair and replacement Hydraulic Press machine

Purpose: This activity will develop the skill, knowledge and attitude of the trainees to Maintaining the supplementary welding tools and Equipment operation using portable grinding machine.

Method manually repairs lathe machine.

Procedure or Step

1. Interpret and understand the manufacture manuals
2. Wear properly personal protective equipment (PE)
3. Use properly Tools, Materials, & equipment.
4. Disconnect electric from the source
5. Clean the surface of the body of the machine
6. Remove the consumed brush materials
7. Replace or repair the new one
8. Check the operation of the manually operated
9. Check the Replace or repair parts work properly
10. Finalize over all about the machine

Self – Check

Part I choose the correct answer from the following alternative

1) _______ maintenance is regular period planned maintenance which eliminates breakdowns and outages
   A. Routine
   B. Preventive
   C. Corrective
   D. Operation
2) With the increase in cost of preventive maintenance, the breakdown maintenance cost will _______
   A. Decrease
   B. Increase at a faster rate
   C. No change
   D. increase
3) Condition monitoring is the basis of ________maintenance
   A. Preventive
   B. Shutdown
   C. Breakdown
   D. Predictive
4) Which statement describes a characteristics feature of routine preventive maintenance
   A. Maintenance schedule needs to be decide, based on maintenance requirements entered in manual
   B. Maintenance could be done either during the working of the machine or during shut interval down period
   C. Maintenance done at irregular frequencies
   D. Maintenance is performed only if the machine has a fault or defect
5) What type of maintenance is most effective?
   A. Shutdown maintenance
   B. Corrective maintenance
   C. Breakdown maintenance
   D. Preventing maintenance
6) Maintenance that involves a system of periodic inspection and maintenance designed to keeps machine in operation is called
   A. Preventive
   B. Total productive
   C. Predictive
   D. breakdown
7) ________maintenance requires monitoring plant equipment health
   A. Preventive
   B. Schedule
   C. Predictive
   D. Break- down

8) Which of the following is not type of maintenance of machine

A. Timely maintenance
B. Schedule maintenance
C. Preventive maintenance
D. Corrective maintenance

9) Which of the following is systematic approach for maintenance?

A. Problem – Diagnosis – Cause – Rectification
B. Problem – Measure – Diagnosis – Rectification
C. Problem – Cause – Diagnosis – Rectification
D. Problem – Diagnosis – Measure – Rectification

10) Which of the following types of maintenance is done on daily basis?

A. Routine maintenance
B. Breakdown maintenance
C. Ordinary maintenance
D. Special maintenance

11) Which of the following is an advantage of plant maintenance?

A. It increase accuracy of instruments
B. It increase life instrument
C. It decrease plant safety
D. It decrease life of instrument

12) Why is maintenance of a machine necessary?

A. Doing so reduce the production rate
B. Doing so increase the servicing cost
C. Doing so increase efficiency and service life to the machine
D. Doing so helps in the replacement o the machine

13) Casual maintenance of the machine is called

A. Preventive
B. Unscheduled
C. Routine
D. Periodic

14) The main function of fluid and oils

A. Provide lubrication
B. Cool the tool and work piece
C. Wash away the chip
D. Improve surface

15) Which of the following is the most important quality of any lubricant?

A. Low priced
B. Specific head
C. Specific gravity
D. Viscosity

LAP TEST

Instructions: Given necessary maintenance tools and materials you are required to perform the following tasks

1) Practical demonstration of performing preventive maintenance/repairs by replacing grease lubricants on the Hydraulic Shearing machine
2) performing preventive maintenance/repairs by replacing coolants and grease lubricants on the Hydraulic band saw machine

Unit Three: Record maintenance report and storage of Equipment

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:

- Records inventory of tools and equipment
- Storage tools and equipment

This guide will also assist you to attain the learning outcomes stated in the cover page. Specifically, upon completion of this learning guide, you will be able to:

- Conduct, record and document inventory of tools and equipment
- Store tools and equipment safely in appropriate locations

3. Record maintenance report and storage of Equipment

3.1. Records inventory of tools and equipment

3.1.1. Inventory of tools and Equipment

Maintenance of an object requires various kinds of physical goods and they can be grouped broadly into two categories:

(i). ***consumables*** – such as oil and grease in plants, paint in infrastructures, and so on, and

(ii). ***Spare parts*** – items (from components to objects and anything in between) that may be bought new from external suppliers or repaired/reconditioned either in-house or by an external agent.

Inventory management (of materials and spares) is important, as holding inventories implies capital being tied up. Not having enough inventories of tools/equipment and materials may affect the functioning/operation of the object, with serious consequences in terms of availability and cost. In this section we focus on spare parts from the point of view of the maintenance service provider.

3.1.2. Characterization of Tools and Equipment

Tools & Equipment and maintenance are a significant part of most industrial world economies, as illustrated by the statement given below. Equipments and services account for 8% of the annual gross domestic product in the United States.

There are many different ways of characterizing the spare parts used in maintenance, and these include the following.

Repairable versus Non-Repairable Items

An engineered object can be viewed as a multi-level system. The number of appropriate levels depends on the object under consideration. Deciding whether an item is repairable is not a straightforward decision. We distinguish between two types of spare parts:

1) ***Repairable parts:*** Parts that are repaired rather than procured; that is, parts that are technically and economically repairable. After repair, the part becomes ready for use again.
2) ***Non-repairable parts or consumables:*** Parts which are scrapped after replacement.

Non-Repairable Spares The primary question that service providers encounter for spare parts planning is how to place the spare part inventories throughout their service network. Possible options include delivering parts to the field where they are required, channeling the parts through a central warehouse – a two-echelon solution, or a three-echelon solution with a central distribution center and regional warehouses close to customers. Once the distribution network is in place, the next issue is the ordering and inventory policies for the different echelons.

Repairable Spares

Given an item design and a repair network, a level of repair analysis (LORA) determines, for each component in the item, (i) whether it should be discarded or repaired upon failure and (ii) at which echelon in the repair network this should be done. The objective of the LORA is to minimize the total (variable and fixed) costs.

A typical structure of the repair equipment is to have a single- or multi-echelon system. The details of these types of equipment and their operation are discussed later in this chapter. **Other Issues** include the following:

- ***Criticality:*** This is based on the consequences caused by the failure of the part. The unavailability of some parts may shut down a whole unit or plant, resulting in high losses.
- ***Specificity:*** Some parts are custom-made whilst others are generic and common to many objects.
- ***Lead time:*** Many spare parts have a long lead time, especially for custom built items or repairable items that have to queue for service at a repair facility.

3.1.3. Framework for Spare Parts Inventory Management

Figure 20.4 is a system characterization of the real world of spare parts management which shows the key elements and the interactions among them.2

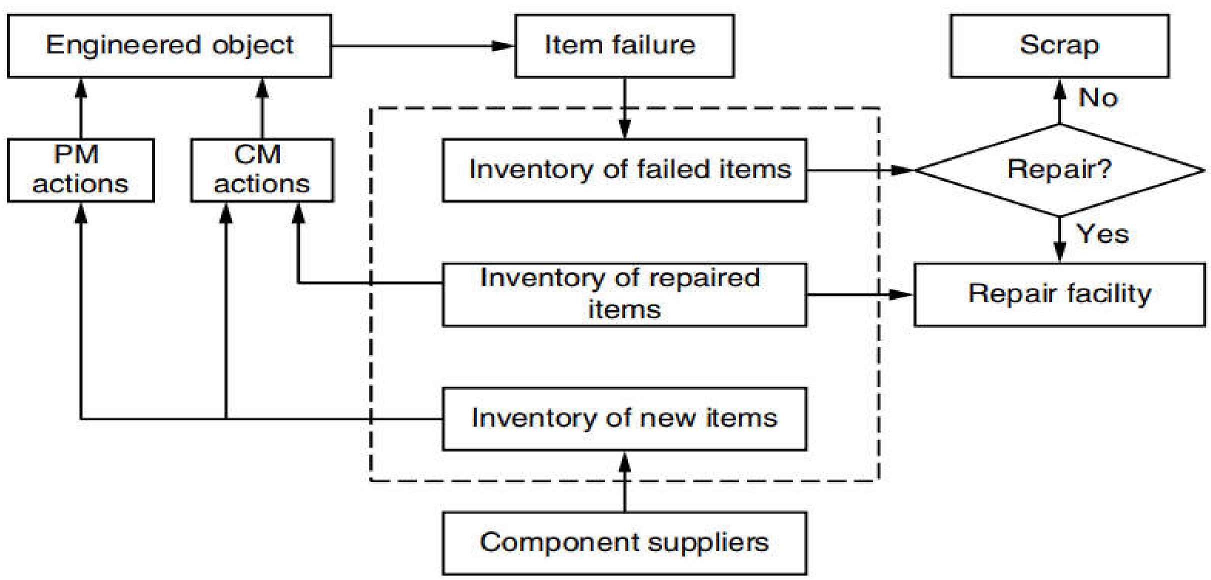

Figure 3.1. Framework for spare parts inventory management.

The key issues we will discuss include:

- Inflow and outflow of items from the inventory;
- Forecasting of the demand of spare parts;
- Inventory control to manage the flow.

3.1.4. Use of Standard-Practice Sheets and Manuals

There are many forms of standard-practice sheets, or standard job instruction sheets, and instruction manuals used in maintenance departments. They are excellent devices for planning work, ordering materials, improving estimating accuracy, and training crafts personnel.

The need for standard-practice sheets also varies with the complexity of the repair and with the degree of skill and the experience of the men performing the work. Most equipment suppliers will provide excellent manuals which, although do not cover all the detail found in a standard-practice sheet, cost little and provide much assistance for maintenance of the equipment. Every effort should be made to maintain a complete supply of these manuals available to the men directly involved in the maintenance of the equipment.

These may be reproduced and divided to provide each craftsperson with a copy if advisable. A work measurement or incentive system based on summarized elemental standards makes some sort of standard-practice sheet a must. Most repetitive repairs can be profitably studied for the best approach, and a standard procedure developed.

A typical standard-practice sheet should include specifications for the tools required, the necessary parts and supplies, a sufficiently detailed print of the equipment indicating the components with sufficient clarity for the craftsperson to follow the instructions, a step-by-step procedure with complete notes to cover any unusual or critical steps, and a close approximation of the time required. The development of these sheets is time consuming and expensive, and rapidly changing conditions and equipment may make them obsolete quickly.

The lubrication and maintenance departments can function most effectively when they have complete records as to lubricant consumption per machine per area. This requires careful inventory (monthly) and recording of amounts of oil and grease issued. Lighting plays an important part. If the storeroom is painted gloss white, if light outlets are well located to obviate glare, and if a comfortable record desk is installed, personnel will keep more careful records.

3.2. Storage tools and equipment

3.2.1. Stores and Material Management

As previously mentioned, stores plays a vitally important role in the overall maintenance management process. Several key indicators of the most important stores-related indicators are:

- Inventory accuracy
- Stock-outs (active inventory)
- Service level (active inventory)
    Hot shot/expedite
    Percent of all deliveries
- Birr value Inventory issue frequency

For example, stock-out percentage is the fraction of occurrences in which the storeroom cannot fill a requisition list for parts or materials because it is out of stock.

Stock-outs should fall in the range of 0–2%.

Another recommended stores performance indicator is turnover. Turnover is the calculation of the average throughout the storeroom (expressed in months).

$$\textbf{Turnover} = \frac{\textbf{Total Value of the Storeroom}}{\textbf{Total Value Withdrawn in a Year}} \; \textbf{* 12 months/year}$$

If turnover is high, it is an indication that the stores value is inflated. If it is low, excessive stock-outs may be the result. The formula is best for broad categories of the stores inventory, as different categories will reflect different turnover rates.

Common categories for storeroom inventory are:

- Recommended
- Turnover
- Category

Insurance items, one-of-a-kind spare equipment; large assemblies; spare parts, for pumps, gear boxes, etc.; hardware, such as nuts and bolts; supplies, housekeeping materials, etc. Little or no turnover, every 2 years, every year, every 6 months, every 1 to 3 months.

The turnover rate should fall within the range of 6–12 months. In addition to tracking inventory by turnover, another effective indicator is tracking inventory by issue frequency. This indicator will highlight inventory based on frequency of use or issue. The goal is to increase the amount of issue inventory and decrease the levels of slow, stale, and no activity. Typical performance indicator ranges are listed below.

- Classify inventory by issue frequency
- Active usage last 12 months 70%
- Slow, no usage last 13 months 15%
- Stale, no usage last 13–24 months 10%
- No activity no usage last > 25 months 5%

It is recommended that action be taken to address why inventory is ‘‘on the shelf’’ yet hasn’t been issued.

Bulk storage can be an investment that provides benefits in improved efficiency, reduced handling costs, reduced risk of contamination, and simplified inventory. Each product requires its own dedicated bulk storage system, including tank, pump, and receiving line. The tank should be equipped with a water draw-off line, sampling line, and entry to permit periodic tank cleaning. If tanks are equipped with electric heating coils or steam lines, precautions must be taken to prevent overheating and thermal degradation of the lubricant.

Bulk shipments may be supplied in tank cars, tank trucks, or tote bins. Upon arrival of bulk shipments, each product should be inspected visually for clarity and cleanliness and checked for viscosity with a handheld viscometer. Prior to unloading, each tank should be gauged to ensure sufficient room. Tank lines and valves should be checked to ensure that the product is being unloaded into the correct tank. If dedicated lines and pumps are not being used, the system should be flushed with one to three times the volume of the lines to prevent cross-contamination of products. Samples should be obtained from the tank after unloading and labeled with product name, date, invoice number, and batch number. The samples should be stored for at least 6 months.

Self – Check

Give Clear and precise answer for the Question

1) What are the two broad categories that require Maintenance of an object in inventory?
2) Distinguish between two types of spare parts in inventory of tools and equipment?
3) What are the key issues in tools and equipment inventory?
4) What are the standard manuals and sheets in preventive maintenance?
5) Mention the need of the standard manuals and sheets
6) What are the component of a typical standard – practice sheet and manuals?
7) What department is plays a vitally important role in the overall maintenance management process. Mention the key indicators of the most important stores- related

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