Organization and Planning of Maintenance Work on Turbines and Compressors

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1. INTRODUCTION

Hydraulic, gas and steam turbines, compressors are classified according to their working fluid. In turbines the working fluid enters at a high pressure, acquires kinetic energy as it expands to a lower pressure in a ring of fixed nozzles. The stream of fluids undergoes a change in momentum as it flows through passages between blades attached to the rotor and the component tangential to the circle of rotation produces the output torque on the shaft. In compressors, there is a reversal of the processes highlighted under turbines. The two main types of turbines and compressors are the axial and radial flow types distinguished by the working fluid flow direction. The more versatile of these two types however is the axial flow types particularly for turbines.
Maintenance is to cause something to continue in existence at the same level or standard or working order by checking or replacing it regularly. The main objectives of maintenance include:

i. To retain the equipment's in the as built condition as nearly as possible.
ii. To prevent emergency short down.
iii. For safety of lives and properties
iv. Prolong the service life of equipment

Planning for maintenance is highly desirable as the alternative to planning is haphazard or erratic approach to task at hand with attendant negative consequences. If maintenance is not planned, the cost becomes abnormally high and the production output is very low. Planning becomes necessary because:

i. Equipment and machineries involved are sophisticated
ii. To minimize the attendant cost of unexpected shut down particularly labour cost and loss of revenue.
iii. Craftsmen that specialize on specific maintenance tasks can be adequately inform thus increasing the reliability of work done and lower overall cost.
iv. Adequate planning of maintenance operation will ensure that the needed spare parts and materials are available at stores

2. ORGANIZATION OF MAINTENANCE OPERATIONS

Many managers are not aware of the choices to be made among maintenance organizational structures, and that the chosen option can significantly affect maintenance performance. Most maintenance organizations have evolved over time in response to the needs (real or perceived) of the operation. The organization may provide a satisfactory level of service; but often, no careful thought has been given to which structure can best yield optimal results.
The four organization approaches to plant maintenance are

i. Centralization by trade according to specialization.
ii. Maintenance coverage by area
iii. Combination of central and area administration.
iv. Use of multi-skilled maintenance personnel.

Whatever type of approach is adopted, it is often headed by a single person responsible for the operation of the whole department. He carries such titles as Maintenance Manager, Chief Engineer and Plant Engineer. Figure 1 is a typical organization structure with special emphasis on the down-line personnel of the Mechanical Maintenance superintendent.

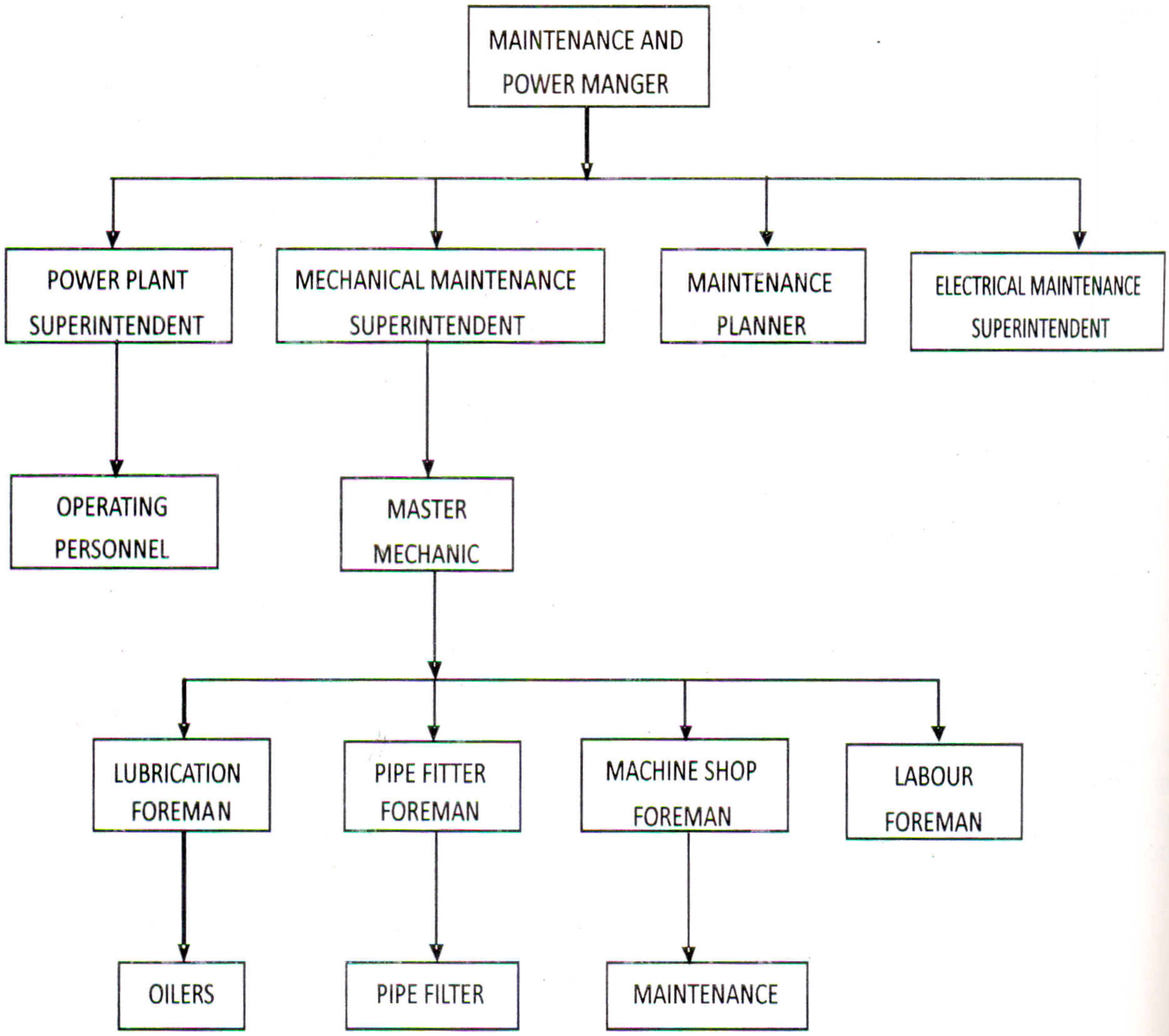

Figure 1: Centralization by trade maintenance organization

3. PLANNING MAINTENANCE SCHEDULE

In order to minimize cost, the most important activity is adequate planning of maintenance 'schedules. Maintenance schedules are either long term or daily. Whichever it is, consideration of emergency-jobs with varying degrees of frequency must also be considered.

Common to both classes is the necessity of making frequent changes and adjustments to meet the current situation. ***Gantt charts*** (see Figure 2 below) are probably still the greatest aid used today in planning maintenance schedule. The alternative in modern plants is the use of computer for information retrieval. Maintenance jobs are often short and usually isolated in contrast to production or operations. Scheduling therefore is more immediate and must be more flexible than operation. Proper scheduling is required to make the best use of craftsmen's time.

a. Gantt Charts:

A Gantt chart is a type of bar chart that illustrates a project schedule. Gantt charts illustrate the start and finish dates of the terminal elements and summary elements of a project. Terminal elements and summary elements comprise the work breakdown structure of the project. Some Gantt charts also show the dependency (i.e, precedence network) relationships between activities.

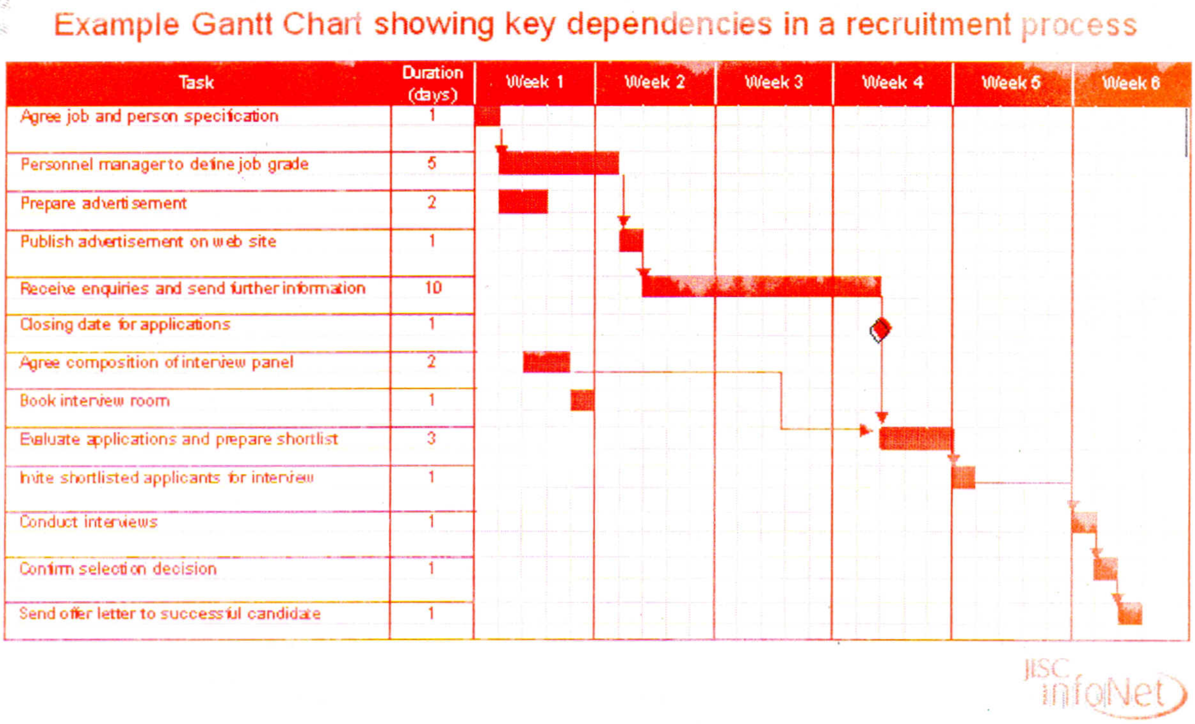

Figure 2: Gantt chart showing key dependencies in a recruitment process

b. **Responsibility for work assignment**

This is primarily for the Plant Engineer (or Maintenance Engineer). However this function could be delegated to supervisors. The advantage is that the supervisors are closer to the job and is in the best position to assign individuals to jobs.

4. DAILY PLANNING AND SCHEDULING

Daily planning for a small sized maintenance crew is best done by the Plant Engineer (or Maintenance Engineer). He maintains a list of craftsmen, checks programs of work during the day and towards the end of the day, prepares the next day's assignment lined up. A bulletin board is often used to show assignments and location of men. The daily work plan shows the location and jobs of each crew and makes it easier to get emergency help with the least possible disruption. It is advisable that all requests for maintenance for the next day, must get to the plant engineer before 2:00pm A regular daily maintenance planning meeting after 2:00pm of interested parties is advisable. Its purpose is to make a comprehensive plan for the next day.

Job tickets for the next day may be distributed to craft leaders before closing time possibly at the tool crib. It saves time and avoids confusion of organizing crews each morning. It is also useful to notify the attendant about tools and materials needed, with requisition accompanying job orders. Completed job- orders should be neatly filed. Before filing, entries should be made on the equipment record showing the date, total labour cost, total material cost, and other important notations.

(a) **Daily scheduling programme**

Variables which affect this scheduling process are priority of jobs, need for emergency repairs and availability of work force and equipment. Experience and knowledge of the particular plants operation, historical data are necessary for the efficient scheduling of any maintenance group.

Maintenance work order is a must for daily works. It may be either of a specific type involving one project or of a blanket type for repeated and routine maintenance jobs. Provision should be made for the work requested, person requesting the work, an estimate of the time required, an estimate of the cost, location and number of the equipment, date start and completed, order number, approval and other data's peculiar to the establishment. When the job is completed, work orders serve as the basic record from which maintenance costs on each item of equipment can be developed and supplies the financially data needed for formal accounting, planning and control reports.

(b) Material requisitions

A material requisition form should be made out as a receipt for all withdrawals of items from stores. In most cases exact requirements are known ahead of time, however provision must be made for needs observed after dismantling equipment.

The authority responsible for the issuing of the materials requisition lies with the Maintenance Engineer or Foreman. On major alteration and overhaul, the plant engineer authorizes the preparation of a bill of materials from which the requisition will be written.

5. ECONOMIC MAINTENANCE CYCLES

Past records and experience may be used to determine the most economical cycle to use for major overhauls. Usage often is the basis for maintenance cycles. Where the rate of usage is fairly constant, it has been found advantageous to put inspections on a calendar date basis. This tends to produce uneven maintenance load. Adequate reference need to be made to the manufacturers' manual during scheduling. To establish a machine maintenance cycle, it is necessary to determine the point of maximum economy as well as the point at which dangers develop. Such points can be determined only by a study of the machine performance with respect to

- i. Quantity and quality of machine output
- ii. Frequency of adjustments and minor repairs
- iii. Probable time serious failures may be expected

A maintenance program is not static but should be in continual process of improvement.

An annual review is a user guide in directing efforts towards a better step in achieving best results.

a. Development of long term maintenance program

Long term plans is meant to provide a stabilized maintenance force and to arrange major jobs so that peak does not culminate into emergencies. Where standards or good and reliable data are available, the most desirable procedure is to assemble a schedule of equipment and compile a man-hour summary of normal maintenance work required by each repair task, separating craftsman hours and helper hours in each. Additionally, experienced and plant policy allows for an estimate of installation work, alteration and removal work. Total estimated man-hours divided by expected normal annual work - hours per man will give the minimum average force. This number of workers is then translated into a minimum skeleton crew. The next step is to consider emergency work and definitely known peak loads. Emergency works could be works imposed by storms, accidents, power failure, operational errors etc. Peak loads consist of such works such as overhauling of major equipment and plant shutdowns. Peak loads are reduced by good planning and organization.

b. Maintenance of continuously operating machines

Special consideration in planning is given to machines that operate for 24hours. For such plants;

- i. Much of the maintenance work can be done only while the plant is shut down.
- ii. Shutdown usually puts an expensive sequence of equipment out of revenue producing activity.
- iii. Emergency shut downs are great constraint to the personnel and may lead to unsafe operations. They are often more expensive than planned maintenance.

Standard method for the overhaul should be developed, together with an estimate of manhours required for complete handling of the repairs work, from takeover by the maintenance crew to release again for operation. Total man-hours for annual maintenance work should be determined, classified according to specialization, and separated into work during shut downs and while running. Commercial schedules will indicate the period during the year in which the plant can be shut down. From man-hour required and calendar hours available, the requisite size of crew can be decided.

c. **Routine inspection and maintenance**

Inspection is meant to determine by observation the need for maintenance or repairs. Maintenance is to correct by physical action the defects uncovered by inspection. Inspection group has the following responsibilities.

i. Determine the safe operating condition of equipment.
ii. Formulate procedures to safe guard individuals from accidents.
iii. Inspect incoming spare parts.
iv. Establish the useful life of systems and equipment.
v. Conduct tests to determine the weak points in machine systems and recommend ways of elimination.

6. MAINTENANCE PLANNING DETAILS

Approval: This entails the permission of the plant engineer for purchases and repair.
Equipment Record: This shows the maintenance history of the turbine or compressor.
Schedule of work ahead: This entails work that can be planned ahead of time. The job is subject to variation while work is on and also, as a result of any emergencies that may arise.
File: Work orders and data on future jobs can be kept with dates.
Daily work programme: This is a program of regular work and emergency jobs for which work orders have just been received.
Daily work force report: Kind and location of job to which maintenance men had been assigned.
Estimate Man-Hours: With reference to past records, a fairly accurate estimate could be made.

7. USE OF COMPUTER IN MAINTENANCE

Based on such advantage as instant recall of data, accurate decisions by the plant engineer. The aim is to gather together all basic information necessary for analysis and decision making in the maintenance programme. The specific operations carried put on the computers are:

i. Recording machinery downtime.
ii. Recording machinery running time.
iii. Processing and calculating equipment cost.
iv. Scheduling maintenance inspections and repairs work
v. Reporting work backlogs.
vi. Balancing work loads of maintenance crew.
vii. Spare parts inventory control.
viii. Scheduling by critical path methods.

a. **Record keeping**

Modern concepts dictate that preventive maintenance programmes and other maintenance operations which can be analyzed through the use of operation research techniques be made on the basis of historical or existing data. Since most equipment in usage has the tendency to fail, it becomes pertinent to predict when the equipment will require maintenance in the future. The first step is to design a data collecting system before analysis is attempted.

b. **Equipment record**

This consists of two types. One is kept for the purpose of recording data on the equipment itself- name, number or symbol, date of purchases, costs, maker and model, location within the plant, current conditions. It is often kept in the Plant Engineer office. The second type of equipment record is that used for entering all details of maintenance and repair work. Either or both of the records may be kept on cards in a loose leaf record book.

c. **Maintenance work measurement and productivity**

Data collection for work measurement must be well organized and detailed in order for it to be usable. The record of maintenance is broken into details. For example, any compressor maintenance will follow the following procedure;

- Blanking off the piping
- Removing the casing
- Internal maintenance
- Replacing the casing
- Re-priming the pump

Note that all operations, apart from internal maintenance is common to all compressor, therefore, further analysis would be necessary to determine the range of times for internal maintenance. Since maintenance work is often repetitive, it leads itself to method study and time study therefore, standards can be set. A good index of productivity applicable to ageing plants or where no significant fresh investments are made is given as Maintenance Cost/Machine or Unit.

8. PREVENTIVE MAINTENANCE

The aim is to make renewal before the failure of equipment and remedy minor defects before they lead to major repairs. Major sources of physical deterioration in turbines and compressors include;

- Vibration
- Corrosion
- Wear
- Lubrication, and
- Abuse.

Vibration: This can be minimized at the design stage. Balancing is effected by placement of mass through a process of static balancing. The machine, also, need to be dynamically balanced.

Corrosion: Corrosion may be prevented or delayed by using more corrosion resistive materials, protective coating or by introducing a sacrificial element. Protective coatings are paints, Asphalt, Water proofing or bituminous coating. Steel parts may be protected by galvanizing.

Wear: This entails careful selection of materials and use of lubricants.

Lubrication: The plant engineer should be responsible for all lubrication works. He is to specify lubricants and frequency of application/attention on the machine. Turbine and Compressor manufacturers' recommendation on oil specification should be followed.

Abuse: This is often a problem of supervision. Constant training and re-training on the proper use and handling of equipment is one method by which damaging treatment of equipment can be reduced. Abuse manifests itself in any or all of the sources of physical deterioration stated above.

(a) Gas turbine maintenance

Basically the gas turbine consists of a compressor that draws in atmospheric air and compresses it to a certain power ratio, a combustion section and a turbine section through which the combustion gases expand. In power generation applications, the power turbine drives a generator.

The mechanical monitoring on a gas turbine includes;

- Vibration levels
- Hydraulic and lubricating oil pressures
- Metal wear
- Oil consumption and acidity

Lubricating oil levels and fuel oil filters should be checked at appropriate intervals.

The Inspection should consist of;

Weekly checks

- External Pipe work
- Conduit and Electrical leads
- Lubricating oil tank level.

Monthly checks:

- Air intake flare and compressor blades
- Magnetic chip detectors.

Six month/Annual checks

- Filters
- Borescope inspection of internal components this is necessary when performance monitoring results suggest the possibility of internal damage.

(b) **Compressor cleaning**

The compressor can be cleaned by either of the following methods;

i. Crank/Soak washing (During Shut Down)

ii. Fired Fluid washing (While in Operation)

Major differences occur between the steam turbine and the combustion gas turbine. The combustion gas turbine is a complete, self contained prime mover. This combustion process to generate energy does not require a boiler. Therefore, the cycle temperatures are considerably higher. The parts that are unique to the turbine are; Combustion caps, liners and transition pieces. These with the turbine nozzles and buckets are called "hot gas path" parts. The entire scope of inspections can be described as standby, running, fuel and hot gas path.

Standby Inspection

This applies to gas turbines that are used intermittently. Checks should be concentrated on battery system, lubricating, changing of filters, check on oil and water levels, cleaning relays, checking device calibrations and other general preventive maintenance. It should be done in off-peak hours.

Running Inspection

These are observations made while the system is still in operations, in accordance with some programmes schedule. Typical running inspection recommended for gas turbine includes;

- Load versus exhaust temperature
- Vibration
- Fuel flow and pressure
- Exhaust temperature control
- Exhaust temperature variation
- Start up time.

The general relationship between load and exhaust temperature should be observed and compared with previous data. High exhaust temperatures are indications of deterioration of internal parts, excessive leaks, axial flow compressor fouling or improper control setting)initial start up data may be used as reference.

Vibration level of the units should be observed. The main causes of vibration are;
i. Non- uniform dirt settling on the working surface of the rotors
Ii. Damaged part on the rotor, wear or bearing wear out.

Fuel System

This should be examined for general fuel flow versus load relationship. Fuel pressures through the system should be observed. Changes could indicate blockage of fuel nozzles or fuel metering elements are damaged or out of calibration. Exhaust temperature of the exhaust gas should be measured. An increase in temperature spread indicates combustion deterioration or fuel distribution problem. If uncorrected, reduced life span of down- stream parts can be expected. Start up time)when the gas turbine was new(is an excellent reference against which subsequent operating parameters can be compared and evaluated. Deviations from normal conditions help pinpoint impending trouble, changes in calibration or damaged components.

(c) Hot gas path inspection

The inspection involves all hot gas path parts. These include the turbine buckets, shrouds, Nozzles, transition pieces and exhaust hood turning vanes.

Major inspection

This involves laying the turbine on the half shell and completely inspecting the axial flow compressor stator and rotor parts, turbine buckets and shrouds, bearings and seals. Recommended work scope for the major inspection is shown in Table 1 below.

PART	ACTION	INSPECTION FOR
Bearing Seals	Clean	Wear, Fouling, Leaks, Wiping, Scoring. Deterioration of parts
Blading	Clean manually, and checked for all loose parts	Foreign objects damage, corrosion, cracks fouling
Buckets	Remove from rotor, checked for loose parts	Foreign objects damage , cracks, corrosion
Turbine Wheel	Clean, checked for loose parts in the dovetail area	Cracks in dovetail area
Journal and Seal Fits	Replace	Wear, Scoring, wear on seal fits
Inlet System and Exhaust System	Inspect, repair, paint.	Corrosion, Cracks, Loose Parts.

9. CONCLUSION

In general, maintenance is best achieved by:

- Define the planner/scheduler environment
  - Understand common maintenance problems, delays and inefficiencies
  - Define the nature of repair (reactive) vs. maintaining (proactive)
  - Sustain the commitment and support of management

- Develop an effective planning program
  - Apply a maintenance assessment process and a proactive maintenance timeline
  - Coordinate the roles and responsibilities of maintenance supervisors and planners
  - Differentiate between reactive, preventive and predictive maintenance
  - Explain work measurement to the maintenance work team
  - Use performance metrics, PM compliance, schedule compliance, backlog, efficiency, and labour utilization
  - Define the essentials of critical path planning

- Manage scheduling and coordination
  - Define the term backlog and its relationship to estimating
  - Balance manpower demand

➪ Create effective job plans
- Prepare a detailed job plan
- Plan individual job activities

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