

Turbine, Generator & Auxiliaries - Level 134

MAINTENANCE

Knowing when to schedule turbine maintenance is one of the most difficult decisions facing generating station personnel. If planned outages are too close together, considerable generating time can be lost; if too far apart, the probability of forced outage is increased significantly.

Some utilities overhaul turbines every three years while others lengthen the time between major overhauls to twice this period or even longer. Within broad limits, the time between major overhauls does not in and of itself determine the reliability of the turbine, generator and associated auxiliary systems. Frequent disassembly, inspection and reassembly of a turbine not only results in loss of maintenance dollars and generating capacity but may result in needlessly disturbing a properly operating unit.

As the cost of maintenance and alternate power sources increases there has been a general increase in the time between major overhauls. This can be accomplished without increasing the risk of forced outage provided the need for overhaul is assessed periodically and the decision as to when to overhaul is made upon engineering judgement rather than a "gut feeling" that the unit will run for another year without an overhaul.

The decision regarding the scheduling of major maintenance is based on several factors:

- (a) progressive deterioration of the turbine heat rate to the point where the cost of outage for overhaul is outweighed by the cost of continuing to run the plant at low efficiency;
- (b) major defects such as increasing bearing temperature, vibration, contamination of lube oil with bearing metal, shaft eccentricity or alignment and control valve maloperation;
- (c) planned outage of the reactor system or electrical distribution system;
- (d) availability of alternate power sources and demand for power from the hydro grid;
- (e) availability of maintenance personnel, and

(f) availability of repair parts and repair facilities.

Regardless of what system is used for planning major plant maintenance, the scheduling of a major overhaul of all four turbines at a station in January of the same year represents a complete loss of touch with reality.

There are basically three approaches to scheduling maintenance for a particular piece of equipment: breakdown, preventive maintenance and engineered maintenance.

Breakdown maintenance allows equipment to operate to failure before it is repaired or replaced. It requires little planning but manpower utilization may be inefficient and downtime is usually unplanned and excessive. There are almost no major pieces of plant equipment which can be operated exclusively under this system. However, a number of more minor components are maintained by repair or replacement upon breakdown: steam traps, reducers, most manual valves and a wide variety of minor piping and electrical systems.

Preventive maintenance makes use of scheduled inspections and periodic equipment overhaul or replacement as a means to prevent breakdowns. Although preventive maintenance is often effective, it is generally expensive and has little value in predicting future performance. In certain systems, particularly those in which deteriorating performance cannot be readily measured, preventive maintenance is necessary to prevent forced outage. A number of non-destructive tests performed periodically on piping systems falls into this category as do routine pump and valve overhauls and certain statutory inspection requirements.

Engineered maintenance tempers the other two maintenance philosophies by using diagnostic and periodic testing and past experience to determine the frequency of overhaul, replacement or repair.

In any maintenance system each piece of equipment is assigned to one of these three categories. When left alone, equipment will always assign itself to the first category.

PERIODIC TESTING

All systems which are essential to the safe and reliable operation of the generating station probably require some form of periodic testing. These tests range from the critical tests of steam admission valves, safety valves, and turbine supervisory and tripping systems to the periodic calibration of pressure and temperature gauges and cycling of infrequently operated valves. Regardless what system is involved and what tests are required the following should be a requirement:

- (a) a list should exist of the required tests including the frequency of testing, procedure to be used for testing and the equipment necessary for the testing;
- (b) a method should exist for scheduling the required tests which includes a method of indicating when a test has been completed;
- (c) for each test there should be indicated under what circumstances the test can be rescheduled or deleted, how this will be accomplished, who may authorize rescheduling a test and who will be informed if a test is not conducted;
- (d) the schedule should state precisely who is responsible for insuring the test is conducted; and
- (e) the schedule should state what action should be taken if the test results are abnormal.

DIAGNOSTIC TESTING

Diagnostic checks should focus on parameters which are indicative of unit performance including:

- (a) changes in efficiency,
- (b) vibration,
- (c) oil and water purity,
- (d) changes in flow, pressure and temperature,
- (e) variation in control system response, and
- (f) changes in operating environment.

It is insufficient to use alarm setpoints as the indicators of abnormal performance. Alarm conditions are operating limits not diagnostic tools. In addition, trends indicating a need for corrective action may develop over weeks or even months and may not be obvious to operating personnel. If the alarm point for bearing metal on a particular bearing is 95°C, and the bearing is currently at 75°C, the operator may not recall it was 55°C a year ago.

It is an important part of the maintenance of steam turbines that the fullest attention be paid to trend indications gained from operating data and, also, that the fullest investigation be carried out into reported abnormalities or defects in operation. With this information maintenance can be concen-

trated most effectively and provision for spares and, if necessary, shop facilities at the manufacturer's plant can be made in advance.

TURBINE OVERHAUL

Before a turbine is taken out of service for overhaul, all materials and spares required should be to hand. In some cases scaffolding and lifting gear can be arranged for special jobs. The sheet metal covers and some lagging can be removed. The important parts of the turbine must be exposed as soon as possible so that the maximum time will be available for correcting defects. A complete schedule of items requiring attention should be prepared and the work planned in proper sequences to avoid interference and delays.

The current operating climate in today's generating stations poses some difficult problems:

- (a) because of the high cost of an outage on a nuclear steam turbine, the overhaul must be completed as quickly as possible. This means there will be little excess time for casual inspections, training unfamiliar personnel and doing work over;
- (b) as the length between overhaul increases the probability of having a large number of personnel who have hard core turbine overhaul experience decreases. Many maintenance personnel may have never seen the inside of a turbine;
- (c) with lengthening periods between overhauls the need for detailed inspections increases. It's been a long time since the turbine was last opened and will be a long time before it is opened again;
- (d) if trained personnel are to be available for the next overhaul, they will need to gain experience during this overhaul.

The sequence of events of a typical major turbine overhaul is as follows:

1. Remove the relevant pipework and the upper half casings.
2. Remove bearing covers and shaft coupling bolts. The thrust bearing is left undisturbed as a fixed point until clearance measurements are taken.
3. Measure blade and gland clearances between the fixed and moving parts.

4. Remove the thrust bearing and the rotors for detailed examination of fixed and moving blades, blade wheels, diaphragms, glands, casing, bearings and other internal parts.
5. Repair glands and restore all radial clearances. Bearing measurements are taken and clearances checked.
6. Replace the rotors and measure clearances of blades and glands.
7. Check alignment of the shaft.
8. Refit the upper cylinders.
9. After remaking the horizontal casing joints and refitting all heavy parts, the final coupling alignment readings are taken and adjustments made if necessary.
10. Refit the thrust bearing and journal bearing covers.

The major parts of a turbine requiring attention during overhaul are detailed below.

Moving Blading and Blade Wheels

While the condition of the blading can be occasionally gauged from operational data such as steam consumption, stage pressure drop and vibration, inspection is the most reliable method of assessing blade condition. The most frequent signs of blade and blade wheel deterioration are moisture erosion, cracking, rubbing, lacing wire erosion and shroud rubbing and erosion. Erosion from moisture generally shows up first on the leading edge of the back side of moving blades where the blades impact with the slower moving droplets of water moving through the blading. On low pressure blading where stellite or chrome steel inserts have been fixed to the leading edges of blading, erosion can be seen as undercutting of the softer steel around the insert. "Fretting" of the blade tips or shroud bands may indicate the presence of standing water within the lower casing.

The blading and shrouds should be inspected for rubbing both between fixed and moving blades and between the rotating elements and the casing. Clearances should be taken between all fixed and moving parts. Rubbing of any kind is abnormal and may indicate misalignment, excessive thrust or journal bearing clearances, past turbine startups or loading in excess of design limits, water induction or component distortion.

Blade or wheel cracking is generally detected at the blade roots (particularly in the LP turbine blades) or at the wheel

to shaft junction. These cracks are usually found by liquid dye penetrant test or magnetic particle test. Any cracks should be ground out and either filled or dressed prior to closing out the turbine. Any grinding on the rotor or blade wheels should be done only by experienced personnel and then only to the manufacturer's limit. If the grinding proceeds too deeply the rotor can be subjected to high stresses and further cracking. Lacing wires occasionally fail due to erosion or fatigue cracking and these should be inspected with particular attention given to the area where the lacing wire joins the blades.

Any unusual condition within the turbine casing should be discussed with the turbine vendor as they are indicative of deeper problems. Additionally, many problems which appear hopeless upon discovery can be corrected at least temporarily by skilled turbine maintenance personnel.

Nozzles and Diaphragms

Most of the comments regarding moving blades are equally applicable to the fixed blading. Moisture damage frequently shows up first on the trailing edge of the inside of the blades as an erosion or loss of material. Diaphragms should be checked for cracks. Checks should also be made for distortion and proper fit in the casing grooves. The seal between the diaphragm and shaft should be examined for evidence of rubbing and erosion. The diaphragm halves are often removed from the casing grooves so that the latter may be cleaned. The diaphragms must be allowed to accommodate thermal expansion in the casing grooves and corrosion products or misalignment can result in seizing and distortion.

Casing

The horizontal flange between the upper and lower casing halves should be carefully inspected for evidence of steam cutting. The casing and bolts should be inspected for cracking by magnetic particle or dye penetrant test. Cracking is most likely to occur at the threads of the bolts, at the outside surface of the casing and where the diaphragms and carrier rings join the casing. Particular attention should be given to edges and notches in the casing which can act as stress raisers.

The inner casing should be checked for evidence of erosion and corrosion particularly in and around the horizontal casing joint and where extraction steam or steam to the auxiliary separators leaves the casing. The lower part of the casing should be checked for evidence of standing water which could indicate blocked or inadequately sized drains.

Glands

Indication of the condition of the casing glands may be judged by excessive gland seal steam consumption or by the pressure necessary to seal the glands. Dissolved oxygen level in the feedwater or excessive air extraction requirements may also indicate faulty glands.

When the labyrinth glands are opened, they should be cleaned, straightened if necessary and adjusted to correct clearances. Badly worn or damaged sections should be replaced.

Some attention should be given to the axial and radial shaft landings. If there is heavy damage due to rubbing or foreign matter, the turbine manufacturer should be consulted.

Bearings

A thorough examination should be made of bearings for wear, grooving of the bearing metal and shaft, loose bearing metal, correct contact surface and possible evidence of electrolysis. Although electrolysis is not a frequent problem, it can occur if the shaft grounding device is not making good contact. The problem is accentuated in saturated steam turbines where the wet steam promotes static charge formation on the rotor. The dissipation of this static charge is normally accomplished by the shaft grounding devices but if forced to the voltage will dissipate through the journal bearings causing pitting or the thrust bearing causing bearing material loss at the trailing end of the shoe.

The condition of oil orifices, including the area for high pressure jacking oil, oil throwers, baffles and the cleanliness of all oil and water passages are checked. It is usual to measure and record bearing clearances. For this purpose a bridge gauge is used and the measurement is compared with previous records. Variations will indicate bearing wear or settlement. A typical permissible clearance is 1 mm per meter diameter of journal. Modern bearings are of the spherically seated type and the fit in the housing is checked for tightness and alignment, adjustments are made if required.

Main thrust bearings are of the usual Michell (Kingsbury) type and normally little wear is experienced. The pads, however, should be checked for freedom of movement.

Emergency Stop Valves and Governor Valves

The emergency stop valves should be periodically disassembled and checked for proper clearance between the valve spindle and bushing. Scaling, galled areas and scoring should be eliminated. The seat and disc should be examined for wear

damage and cracking. The strainer should be inspected for deposits and damage and should be cleaned, repaired or replaced. The sealing surfaces should be inspected for steam cutting.

The oil piston should be inspected for contamination, rust, wear and freedom of movement.

Studs and Bolts

The bolts and studs used to form steam tight joints at high temperatures are made of creep-resistant material. The practical requirement for these bolts is that after extended number of hours of service the initial strain must not relax to the point where they exert insufficient stress to keep the joint tight. On the other hand, the material must have sufficient ductility to be retightened a number of times without cracking.

These bolts must be treated with reasonable care if they are to adequately perform their function while surviving in a rather hostile mechanical and thermal environment. The strain on the bolts is of particular importance. To enable creep-resisting, high tensile strength bolts to be accurately strained one of three possible methods of tightening is employed:

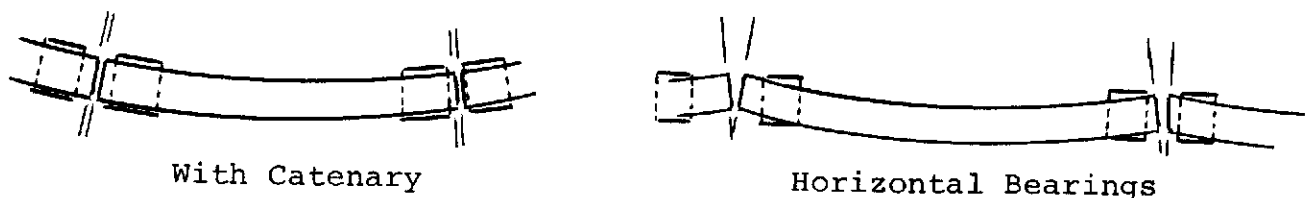
- (1) By means of a torque wrench. This method is generally used on small bolts and requires that the mating threads are reasonably free to move and do not produce a significant torque of their own. The torque wrench used for these operations should be calibrated before use and checked afterwards.
- (2) By heating the bolts and turning the nut a specified number of degrees or number of "flats". The heating of bolts is a common method of tightening the HP turbine casing bolts (LP casing bolts are generally tightened with a torque wrench). High pressure bolting materials generally have low impact strength and, in consequence, are prone to failure by cracking, even at room temperature, if subjected to any form of impact or hammering. Therefore, the most convenient and practical way of producing the necessary bolt loading is by tightening the nut when the bolt has been expanded by heat. The material used for turbine bolts normally has a lower coefficient of linear expansion than the flange material, so once the

bolt is properly tightened, the "squeeze" on the flange will increase as the joint assembly is heated.

- (c) By hydraulic stretching of the bolts to a given strain and then hand tightening the nut. This method is accurate and usually quicker than heating but the hydraulic jacks necessary for large diameter bolts are bulky and difficult to handle.

Shaft Alignment

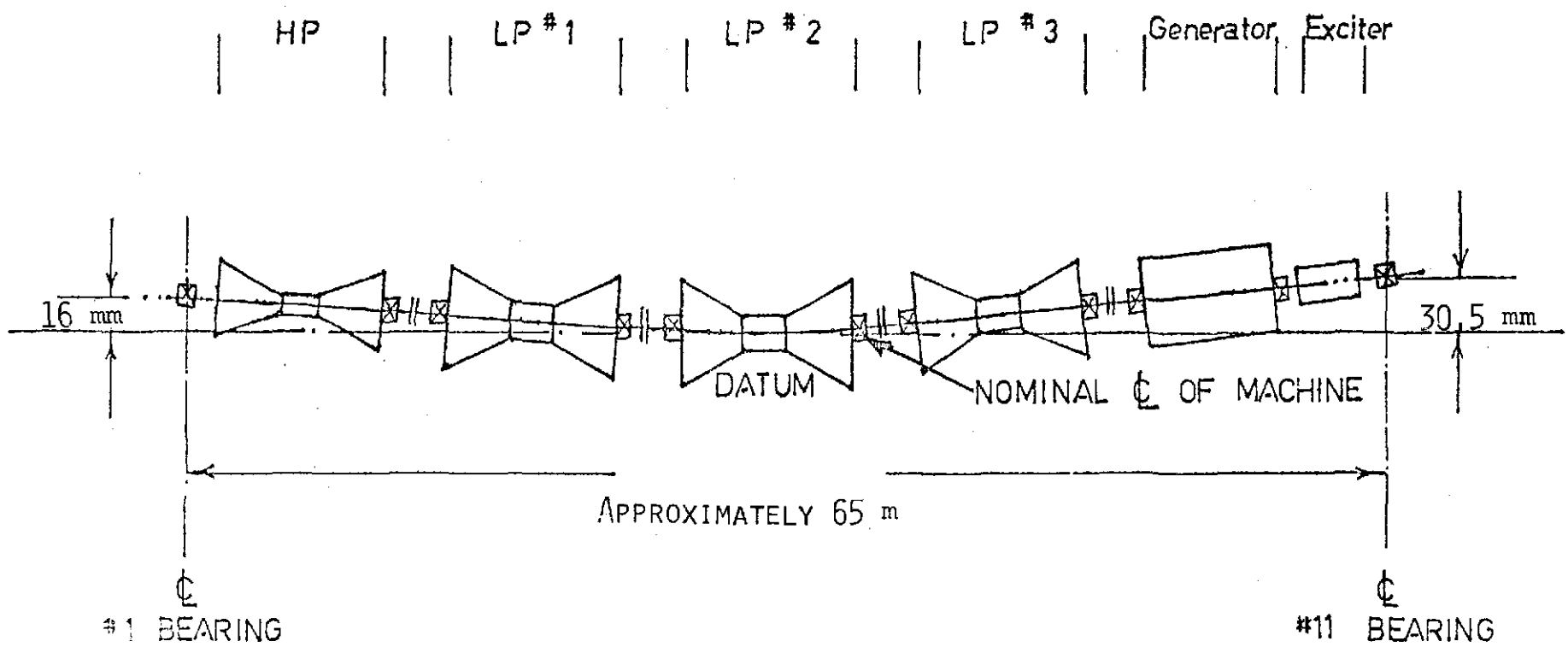
Figure 7.1 shows the general arrangement of a large saturated steam turbine with one HP cylinder and three LP cylinders tandem compounded. The rotor in each cylinder is supported by one bearing at the end of each rotor and the coupling between each rotor occurs between adjacent turbine bearings. This allows the flexibility of each rotor to be independent of the other rotors and enables independent balancing and removal of each rotating element. Since each shaft has an elastic deformation due to gravity the entire line of shafting must lie on a curve and the bearings are lined out to suit this static deflection or "catenary" as it is called. Although it should be obvious, it is worth mentioning that the center of rotation for the unit is the center of this catenary rather than a horizontal line. The couplings between individual shafts are therefore aligned to join the shafts in this catenary. Figure 7.2 shows the type of bearing and coupling alignment used to reflect this catenary and compares it to the alignment which would exist if the shafts were mounted horizontally.



Effect of Shaft Catenary On Bearings And Couplings

Figure 7.2

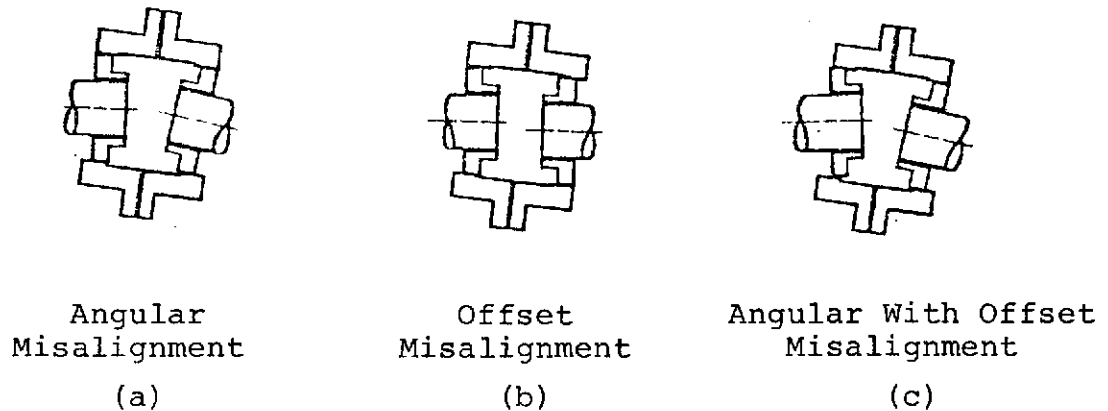
There are two basic types of misalignment which can exist in this type of shaft: misalignment of the shafts to each other (shaft coupling misalignment) and misalignment of the shafts to the bearings (bearing misalignment).



Typical Shaft Catenary

Figure 7.1

There are two types of shaft coupling misalignment: angular, where the center lines of the two shafts meet at an angle (Figure 7.3(a)); and offset, where the center lines are parallel but offset to one another (Figure 7.3(b)). Figure 7.3(c) shows a combination of the two.

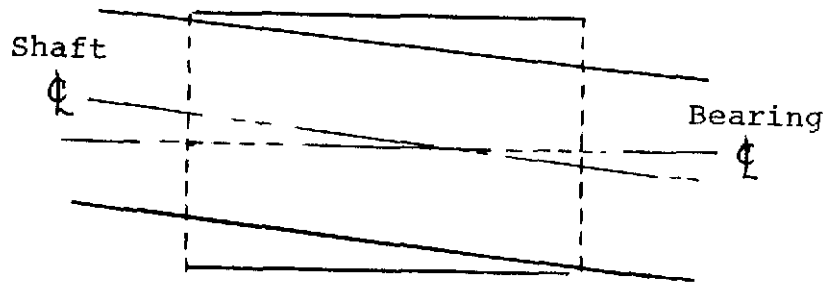


Coupling Misalignment

Figure 7.3

Coupling misalignment, even with flexible couplings, results in axial and radial forces which produce axial and radial vibration. This is true even when the misalignment is within the limits of "flexibility" of the coupling. The size of the forces and therefore the amount of vibration generated will increase with increased misalignment. The significant characteristic of vibration due to misalignment is that it will be in both the radial and axial direction. Axial vibration is the best indicator of misalignment. When the axial vibration is equal to or greater than one half of the radial vibration then misalignment should be suspected. It is worth noting that the symptoms of a bent shaft are almost identical to angular misalignment.

Bearing misalignment is shown in Figure 7.4. No vibration will result from a misaligned journal bearing unless an unbalance of the shaft exists. The reaction of the misaligned bearing to the unbalance will produce vibration in both the axial and radial direction. In this case the misalignment results in an axial component which is generally small when compared to the radial component.



Bearing Misalignment

Figure 7.4

The approximate alignment settings are obtained during erection by means of a taut piano wire passed through the bottom half of the turbine casings, pedestals and stator core. Then by means of an internal micrometer, the horizontal distance between the wire and casing or bearing can be measured from both sides of the horizontal joint faces and the casing and pedestal positions adjusted to centralize the wire within the machine. Similar measurements are taken on the vertical axis to the bottom of the casings and by accounting for the sag of the wire, it is possible to adjust the casings to the static catenary of the unit. Alternately a precision telescope or, more recently, a laser may be used for this purpose. The rotors are then used to obtain final settings by adjusting the bearings to give concentricity and parallelism of coupling faces.

The permissible error of coupling alignment readings is extremely small and a total error of .025 mm is usually accepted as being the limit.

After installation of the rotors and their couplings, dial gauge readings are taken on the shafts at each coupling as the rotor is revolved through 360°.

Clearances

The efficient operation of a turbine depends to a large extent on the maintenance of the correct clearances between fixed and moving elements. Excessive clearances result in increased steam consumption while reduced clearances may result in blade rubbing.

When a turbine is erected the clearances are carefully set and a record is kept at the station. When the top halves

of the casing are removed the clearances should be checked against the record. Care must be taken to ensure that the rotors are in the running position when taking measurements. Provision is usually made to move the rotor axially to a position for lifting.

Maintenance Records

It is essential that good records be kept of all turbine maintenance: casualties, significant events, general chronology of each overhaul, alterations, replacement of components and all numerical clearances and measurements. Experience has proved that the more detailed these records are, the more valuable they become. There simply is no substitute for knowing exactly what was seen, done and thought the last time the unit was worked on.

This is particularly important when few people exist who were involved in the last overhaul, but even when such personnel exist they may not remember everything they saw and did.

ASSIGNMENT

1. Outline the basic factors to be considered in turbine maintenance.
2. What factors influence the decision as to when to schedule a major turbine overhaul?
3. Outline a program of preparations prior to shutting down a turbine generator unit prior to overhaul.
4. Discuss the items which should be examined during overhaul including:
 - (a) blading
 - (b) glands
 - (c) diaphragms and nozzles
 - (d) alignment
 - (e) thrust bearings
 - (f) radial bearings
 - (g) casing
 - (h) casing drains
 - (i) rotor
 - (j) evidence of presence of water
 - (k) clearances
 - (l) turbine flange faces