CHAPTER - 8
Boiler Operation & Maintenance

BOILER OPERATION:

Introduction:

Not many years ago boiler house was getting very little importance and was usually tucked away in some remote corner. Over the years the importance of the boiler has been realised and personnel operating this plant now need a high standard of skill and knowledge. This is mainly because major portions of the operating costs are incurred in the boiler plant. A boiler consumes a huge quantity of fuel, the cost of which has increased considerably. Every kJ of heat, which can be saved, lowers the cost and increases the efficiency of the station.

To compile a detailed list of duties and responsibilities for personnel operating a boiler is difficult. Boiler operation often varies with the age and design of equipment, operating requirements, operating personnel changes and new concepts of how to treat recognized symptoms of trouble.

A major responsibility of the operator is to keep the boilers in good operating condition. The primary concern in the operation of steam boilers, regardless of pressure or type, is safety. Like any pressure vessel, boilers represent potential risks to personnel and property. Good operating practices result in the maximum reliability and efficiency.

In the interest of safety, manufacturers, engineering societies, and most, important, governmental jurisdictions have set forth rules for steam boiler operation and preventive maintenance. The engineers and boiler operators should be familiar with these rules specifically applying to their local situation.

The objectives of Operation Management:

Following should be the objectives of Operation Management:

a. Operation of units at minimum partial loading and maximum availability.
b. Operation of units at rated parameters.
c. Efficient Control of Water Chemistry.
d. Operation of plant at minimum demineralised water makeup, consumption, auxiliary power consumption and coal consumption.
e. Operation of plant and accessories at optimum efficiencies in sustained manner.

Practices adopted for achieving the above objectives are as follows:

a) Systematic monitoring and reporting systems for operation, maintenance & efficiency management.
b) Daily coordination meeting with Head of department to discuss:
    - Operational events and daily plan

- Analysis of abnormal events and remedial measures.

c) Merit order rating
   - Continuous monitoring of important operational parameters having cost implications.

d) Minimum forced tripping

e) Tripping Committee for analysis of cause.

f) Feed back to / from other plants.

g) Analysis of outages / categorizations.

h) Easy availability of operating instructions, manuals and other literature to operating engineers and staff.

i) Efficient up keep of instruments, auto loops, annunciations, protections and interlocks.

j) Good house keeping.

k) Good working environment.

l) Proper training & awareness program.

Key Operation Areas:

There are eight primary areas of the boiler itself that should he examined or inspected regularly.

Water level: The most important maintenance inspection is to check the boiler water level daily. Insufficient water causes pressure vessel damage or failure. At a minimum, steel in the pressure vessel could overheat. The condition could change the pressure withholding capabilities of the vessel, necessitating vessel repair or replacement.

Boiler blow-down: Steam boilers should be blown down to maintain recommended dissolved solids levels and to remove sludge and sediment as and when needed.

As the boiler takes on makeup water the solids concentration builds up. Solids accumulate in either dissolved or suspended form. Unless they are controlled dissolved solids promote carryover of water with the steam causing water hammer and damaging piping, valves, or other equipment. Carryover also raises the moisture content in the steam, affecting proper operation of equipment that uses steam.

Suspended solids, which cause sludge or sediment in the boiler, must be removed because they affect the heat transfer capabilities of the pressure vessel. Sludge buildup leads to problems ranging from poor fuel-to-steam efficiency to pressure vessel damage.

Water column blow-down: Water columns on steam boilers should be blown down once each shift or at a minimum once a day. This action keeps the column and piping connections clean and free of sediment or sludge. The water column also must he kept clean to ensure the water level in the gauge glass accurately represents the water level in the boiler. The gauge glass

connected to the water column is the only means of visually verifying boiler water level.

The low-water cutoff should be checked once a week by shutting off the feed water pump and letting the water evaporate under normal steam conditions at low fire. The gauge glass should he observed and marked at the exact point at which the low water cutoff shuts down the boiler. The test verifies operation of the low-water cutoff under operating conditions. The low-water cutoff also should the removed and cleaned every six months.

Water treatment: Proper water treatment prolongs boiler life and ensures safe and reliable operation. Treatment programs are designed around the quality and quantity of raw water makeup and system design. A qualified water management consultant should direct them.

Flue gas temperature: Flue gas temperature is a good indicator of boiler efficiency changes. The temperature should be recorded regularly and compared to those of a clean boiler under the same operating conditions. Accurately determining the affect on efficiency requires that the firing rate and operating pressure be the same.

A rise in flue gas temperature usually indicates dirt on the fireside of the boiler or scale on the waterside. As a rule of thumb a 40-deg F rise in temperature reduces boiler efficiency 1%. The cost of fireside cleaning should be compared to those of lower operating efficiencies to determine the minimum temperature rise at which the fireside should be cleaned. Other factors also affect flue gas temperature. For example, a rise in stack temperature may indicate a baffle or seal in one of the boiler's passes has failed.

Waterside and fireside surfaces: Waterside and fireside surfaces should be inspected and cleaned annually. A visual inspection provides an early warning that the vessel needs repair or water treatment or that combustion needs adjustment. Inspecting and cleaning water-column connections should receive special attention. Soot in the breeching is a fire hazard and can cause severe combustion-related problems.

Safety valves: Safety valves are the most important safety devices on the boiler. They are the last line of defense for protecting the pressure vessel from overpressure. Once a year, the operating pressure should be tested by bringing the relief valve to its setting. Valves should pop and reseat according to the valve stamping.

Refractory: Refractory protects steel not in direct contact with the water from overheating. It also helps maintain proper burner flame patterns and performance. If the boiler remains on all the time, refractory should be inspected twice a year. If the boiler cycles more frequently or is turned on and off daily, refractory should be inspected more often.
Heating and cooling refractory a lot shortens its life considerably. It cracks and eventually fails. Hot spots on the steel that the refractory protects

indicate refractory or gasket failure. If a hot spot is found, the cause should be determined and repaired immediately to prevent the steel from failing.

Start-up Operation:

After a boiler is has been properly cleaned and it has been ascertained that all debris is removed it is advisable to take the following steps for start-up of the boiler, which are expected to be generally in line with those recommended by the boiler manufacturer. However, the boiler manufacturer's instructions must be adhered to:

- It is to be ensured that no men are in the boiler; man and mud hole covers must be fitted in position.
- It must be determined that all mountings and fittings are in position and the auxiliaries are in good working order.
- Water must be filled just over the bottom nut of the gauge glass to allow for expansion of water when heated.
- When raising steam in a cold boiler as the automatic controls are not available for service, the boiler must be manually operated until it carries certain pressure and then automatic devices may be cut in after ensuring that they are all tested and reliable.
- Reliance must not be placed on automatic controls during critical stages of lighting up and bringing boiler on the line. Strict manual check-up and vigilance must be maintained.
- During the period of raising steam, water level must be regularly observed through the water gauges directly fitted on the boiler, at frequent intervals. Until normal working conditions are reached, indirect water level indicator may not be relied upon.
- No reliance should be placed on low water alarms; automatic feed water regulators etc. until the boiler steams steadily. However, they should not be neglected either.
- When the pressure in the boiler is about 50 psig (3.5 kg/cm^2) below the range pressure, the drains on stop valves should be opened after which the by pass or equalizer valve must be opened first and then the main stop valve opened only thereafter.
- Preferably for a few hours the boiler should carry about 20 to 25 percent of full load until combustion conditions are stabilized.
- After a new boiler is put in service in the manner stated above and after 300 working hours the boiler should be shut down for routine inspection.
- All valves must be examined if they operate smoothly.
- A tool should preferably be passed through the tube lengths specially those in radiant zone to ascertain that the passages are clean.
- Brickwork must be examined and attended to where necessary.

- Fuel firing equipments must be examined that they do not bind or touch anywhere and that they are free to take up the expansion.
- It must be observed that the baffles are in position and not dislodged.
- Soot blowers must be examined for accuracy of travel.
- Internal baffles in drums should be dismantled and internal inspection should be carried out to detect the presence of oil sludge etc. or any other abnormality.
- Follow-up all flanged joints of steam piping. Check if dampers are free to move and operating gear devices are in good order.
- The boiler may then be put into service as directed by the manufacturers. After 1000 hours of service, the same exercise as mentioned above should be repeated.

Good Practices for Normal Operation of Boilers:

- Proper records of all operations and inspections should be maintained. The records for boiler performance must show the time, boiler pressure, steam temperature at the inlet and outlet of superheater, rate of evaporation, rate of feed flow, feed water inlet and outlet temperatures, undue leakages from pump glands, draught readings at boiler economiser and air heater exit, air and gas temperature at entry and exit of air heater, gas temperature at entry and exit of economiser, water temperature at entry and exit of economiser, current reading of forced secondary and induced draught fans, speed of the fan if variable type, quantity of raw water used, bearing temperature of fans, rate of consumption of fuel, CO_2 and O_2 readings, occurrence of water shortage in boiler, frequency of soot blowing, condition of feed water, chemical dozing, concentration of solids in water, frequency of blow down period, testing of alarms, and safety devices, leakages from valves and frequency of ash removal and name of persons responsible for boiler operation.
- The boiler house records hourly or per shift must be examined every day by the plant engineer and any departure from routine or significant event recorded like flue gas explosion or shortage of water in a boiler must be investigated and set right.
- If inaccuracy of the instrument is suspected they must be inspected and calibrated.
- To derate a boiler and to work it at turn down ratio the burner nozzle size is required to be reduced and an air blower of a smaller capacity provided to prevent excess air to ensure complete combustion, and which will prevent frequent on and off operation of a boiler which would create thermal shocks due to which the tube ends in the hot zone may leak.
- The burner assembly must be cleaned periodically and a consistent flame configuration maintained.
- The target must be 13 to 14% CO_2 and no O_2.

- Excess air is the cause of all ills and reduces efficiency. It is detectable by reduces CO_2 level.
- If the burner is oversized the flame may be carried away from the confines of the furnace overheating the tube ends in the reversing chamber of a smoke tube boiler.
- Calorific value of CO is 2430 kcal/kg and that of C is 8084 kcal/kg. It means that incomplete combustion of Carbon resulting in formation of CO results in loss of 2430 kcal/kg out of available 8084 kcal/kg (meaning thereby that around 30% of available Calorific Value goes waste. Thus maintaining high CO_2 level at the chimney base cannot be overemphasized.

Practical Hints for Successful Boiler Operation:

- High capacity boiler may operate very uneconomically at low loads. Hence large boilers should not be operated at very low loads, in general.
- After a boiler is in regular use exposed flanges should be lagged, instruments should be checked for accuracy against standard apparatus, feed water regulators, remote water level indicators and low water alarms inspected and adjusted and dowelling of all motors and bearings of fans, pumps and other auxiliaries attended to.
- The principal aim of a boiler operator is to operate a boiler safely as nearly as possible under design parameters as regards evaporation, steam pressure, final temperature and produce steam of required quantity and quality at lowest practical cost.
- Continuous supervision of boilers by the boiler house personnel is necessary and the personnel to attend a boiler are not allowed to leave the post for more than a few minutes at a time. Therefore for his personal comforts facilities must be provided in the boiler house.
- An operator must observe the water level in the gauge glass, blow down water column on each boiler after operating all the cocks and observe that the water smartly returns back in the glass. He should check the pressure in the gauge if it is within the operating limits. He should peruse the remarks column of the logbook if any abnormal condition had occurred in the last shift.
- Some of ideal conditions are under the control of boiler operators and other fall within the jurisdiction of steam users and other authorities.
- The steam demand depends upon nature of plant using steam. In power stations and large industrial complex, the load could be fairly constant for several hours and the fluctuations could be anticipated with regular frequency and approximate time of incidence. In case of rolling mills, steel plants electric traction etc. load is subjected to violent fluctuations depending upon the particular period of the day.

The boiler operator must get acquainted with the periodic variations of load and anticipate intermittent fluctuations and get ready to combat the load variations. Peak efficiency could be obtained in the range of 60 to 90

percent of rating. If the load is below 30 to 40 percent of rating 5 percent decrease in efficiency may be expected.

The response to load variations depends upon method of firing fuel. In oil gas and pulverized coal firing, immediate control could be established within the range of operation of the supply source burner regulation.

In automatic stoker firing, certain degree of flexibility is provided to control within the limits the rate of combustion by additional supply of fuel and air. When increased steam demand is expected, large bank of fire is built up and preparation could be made in advance for increase or decrease in load.

Where load is likely to fluctuate, the design of the boiler must be such that it is capable of adjusting itself certain sporadic changes in load.

For basic load changes concerned authorities have to decide on following factors:

Accuracy of prediction of maximum steam demand, change of load variations, numbers of boilers in service, flexibility of combustion equipment and boilers, automatic control regulation, boilers on constant load and stand by units banked to meet fluctuations. However attempt to constantly follow erratic changes of load by boiler operators by constantly adjusting firing condition is not a good practice.

Basically for load fluctuations instead of depending upon the storage capacity and competence of a boiler operator initial selection of the boiler, suitable size of furnace volume and firing equipment commensurate with available fuel need attention.

Water content of a boiler is a useful storage of heat and a boiler having large water content will act as a steam accumulator and store and liberate heat in excess of the mean rate of generation corresponding to fuel consumption.

Variations of output will affect the steam pressure, which should be suitable within the range of efficient performance of steam users.

It should be the aim of a boiler operator to maintain boiler working pressure at the designed value which is achieved by balancing heat liberated in furnace and steam released from the boiler.

- Besides the load fluctuations effecting the pressure in a boiler, certain other factors also cause variations in pressure which could be due to sudden changes in feed water temperature, soot blowing, changes in calorific value of fuel and intermittent feeding. To avoid thermal stresses, variations in feed water temperature should be avoided and feed water admitted at an even rate. Feed check valve should not be fully open or fully closed when a boiler is generating steam and this is the function of automatic feed water regulator.
- Changes of characteristics of fuel could effect distribution of heat and require adjustment to draught control air distribution and CO_2.

- Incorrect feed temperature, excess air supplied to furnace, delayed combustion, deposits of soot, ash and other products of combustion, fouled economiser and rear pass of boiler, moisture carried by steam, low steam pressure, fouling of superheater tubes and discharge of steam from safety valve may cause variations in final steam temperature.
- Low feed temperature, excess air supply, fouled economiser, fouled tubes in radiant heat zone, discharge of safety valves, delayed combustion etc. can raise super heater temperature.
- Deposit of ash soot etc. on superheater elements, moisture in steam, low steam pressure can lower the superheat temperature.
- The final steam temperature will be high when a boiler is initially lighted up on account of excess heat generated in the furnace to warm up the brickwork, structure casing etc.
- Sudden increase of forced draught air may by radiation temporarily raise the steam temperature, which normally subsides when a boiler steams steadily.
- During any emergency it is the duty of a boiler operator to minimize damage, stabilize operating conditions of the boiler and maintain maximum state of reliability.
- During any casualty it is advisable to put the boiler under manual control and observe the water gauge glass fitted directly on the boiler and which if not visible from firing floor level a man should be directed to stand near the gauge to give indication about the water level in the boiler.
- If a water gauge glass bursts watch should be kept on the other gauge glass and in the meantime a new glass fitted with care.
- A boiler must be cut out of service unless there is some reliable indication of working water level.
- If a boiler tube bursts or heavy leakages noticed, the boiler must be placed under hand feed control and the automatic feed water regulator by passed. Further desirable steps are:
    - Steps should be taken to reduce load and boiler taken out of service. The rate of firing should be reduced or the burners extinguished as the case may be and maximum induced draught capacity employed to minimize steam leakage into boiler room.
    - To control casualty, close all dampers including forced and secondary ones, increase traveling grate to maximum speed after cutting out coal feeds draw ashes and fire from the hopper as fast as it is discharged, lift safety valves to relieve steam pressure, continue feeding the boiler by fully opening the feed check valve until the boiler is cooled.
    - When the boiler pressure has fallen below the range pressure and fires are out, close the boiler stop valve. When the pressure has dropped to less than 50 psig so that there is not much danger of steam blowing in

the boiler room, stop induced draught fan and try to locate the faults and then blow down water.

- Do not continue to feed water if the cause is due to low water or if the steam leak is so large that water level cannot be maintained in the gauge glass.
- Inform the Boiler Inspector concerned within 24 hours of the mishap and do not clean the boiler or carry out any requirement as the evidence of the cause of accident will be destroyed unless suggested by the Inspector after the boiler is inspected by him and cleaned subsequently. Inspect other tubes for evidence of erosion by escaping steam or distortion due to heat.

- If the brickwork is saturated with moisture it may have to be dried out after the boiler is repaired.
- In minor flarebacks or puffs, if fire is not extinguished the burner need not be cut out but it must be ascertained if any damage is caused.
- In major flarebacks or flue gas explosions, the following is advisable:
  - Oil burners must be shutoff, close the main stop valve, adjust or stop feed pump to prevent high water in the boiler, speed up fans to clear the furnace and flue passages of unburnt oil and gases. Check spring tension of the burner shut off and solenoid valves.
  - Inform the Government Boiler Inspector about the incident and after his inspection any damage to brickwork or any other structure should be repaired as suggested by him and then the boiler put into service.
  - To obviate flarebacks do not allow oil to accumulate in furnace. If burners accidentally get extinguished, shut off oil, purge furnace and setting of unburned oil and gases. Light the burner by torches and never attempt to light a burner from hot brick wall. Always stand clear when lighting a burner to avoid injury in case a puff occurs.
- Panting of a boiler is caused due to inadequate air supply, which are in fact series of small puffs. If adequate air is not supplied it may lead to major flarebacks.
- Water in a boiler is normally maintained at about mid level of a gauge glass. If water goes out of sight at bottom nut of the glass low water casualty should be deemed to have occurred. If the water goes out of sight at the top nut of the gauge glass, high water casualty should be deemed to have occurred.
- By merely looking at the gauge glass it is often difficult to distinguish low or high water casualties, as the glass looks the same when empty or full. But if the droplets of condensation are found tricking down from inside of glass, it is an indication of empty glass and absence of them indicates that the glass is full. To clear the doubts water gauge glasses must be tested. After trying the water gauges if the water level in a boiler is found low, shut off fire, close the feed check valve and never attempt to restore the

water level, close stop valve, lift safety valves by hand to relieve the pressure, secure the fans, allow boiler to cool slowly and open superheater drains.

- After the boiler is cooled, inspect the boiler if any damage is caused due to low water, informs the Boiler Inspector and get the boiler repaired as recommended by him.
- Low water level in a boiler is to be considered as a most serious lapse on the part of an operator as it damages the boiler and it is his main duty to maintain water level under any circumstances. Too much diversification of a boiler operator's duties may cause low water in a boiler if too much reliance is placed on automatic appliances besides distortion, bulging and other defects, a boiler may explode causing serious damage to life, limb and property.
- When filling an empty boiler in a battery with those in service large quantity of water will flow in it, as its pressure is nil. In which case an operator must observe that the boilers in service are not robbed of their legitimate share of water or an accident due to shortness of water may be expected.
- If a feed pump fails to deliver water in a boiler start stand by feed pump. If even the other pump cannot maintain the water level repeat the process as mentioned in case of low water in a boiler.
- If by accident water is fed in idle boilers, pump discharge may be low for the boiler in service. If a common pump is used for boilers in battery, check if feed check valve opening of the boiler concerned is adequate to admit water.
- Failure of feed pump could be attributed to malfunctioning of constant pressure governor, air or vapour bound condition, feed temperature very high for which the pump is not designed or feed by gravity to suction side of the pump is low, faulty pump clearance and malfunctioning or improper setting of the speed limiting governor and no water in the feed tank.
- If power supply to fans, combustion equipments, fuel, feed and other auxiliaries fails, the boiler should be taken on hand control. The main induced draught damper should be opened sufficiently wide to obviate pressure in the furnace with consequent emission of smoke and forced draught dampers closed.
- Unburnt fuel from ash hoppers and in case where pulverized fuel is used from burner pipes and other places where fuel settles must be removed.
- Auxiliary driving motors and gears should be reset in normal starting position so that they may start under minimum load condition.
- When power is restored, close induced draught control damper and start forced draught fan and then other auxiliaries in turn and built load at minimum rate of evaporation consistent with stable combustion conditions, expansion of boiler components checked they are not fouled and load may

be increased by increments and boiler placed on automatic control and then full load taken.

- If oil is found in oil heater drains, leakage of tubes is certain and the heater must be stopped immediately drain water diverted and a stand by heater started. Oil entering a boiler is very dangerous as it causes serious damage to boiler components on which it settles.
- If water has entered fuel oil indicated by sputtering of the oil burner and if action is not taken immediately loss of fire, choked burners and flarebacks may occur.

Practical Aspects of Operation:

All too often, when a boiler problem occurs, the system is overlooked. The emphasis falls on the equipment and not the equipment's function in the overall system. An effective maintenance program must be based on an understanding of the entire system and the function of each piece of equipment. Only an understanding of the system provides the means for preventing the causes of system-related problems and reducing the time spent on the symptoms.

Operating conditions: Operating parameters of the boiler room system should be recorded daily. The data provide a means for evaluating boiler operation trends that affect efficiency, downtime, and maintenance planning. The following data should be recorded.

Feed water pressure/temperature: Changes in feed water pressure affect the system's ability to maintain proper boiler water levels. A leaky check valve on a standby pump or a worn pump impeller may cause a pressure drop. Changes in feed water temperature are indicative of a problem in the deaerator, potential pump seal damage, loss in efficiency, dirty economizer, dirty lowdown heat recovery exchanger, or excessive or insufficient condensate returns.

Boiler water supply/return temperatures: On hot water systems, supply and return temperatures to the boiler are a means for evaluating the system's effect on the boiler and vice versa. The desired operating temperature set point and temperature differential across the boiler should be evaluated against the system design to determine if a potential problem exists. High temperature differentials caused by excessive load or a control malfunction could cause thermal shock and subsequently pressure vessel damage.

Makeup water use: Records of the amount of makeup water used help determine the presence of leaks or losses in the system. They also assist in developing a more effective chemical treatment program. Excessive water use indicates a change in system operation and, therefore, a change in efficiency.

Steam pressure: Steam pressure operating set points usually are based on system design and type of steam use. Pressure changes are typically caused by problems with control settings, burner operation, boiler efficiency, or, most commonly, changes in steam demand.

Leaks, noise, vibration, and unusual conditions: Checking for leaks, noise, vibration, and the like is a cost-effective way to detect system operational changes. For example, tightening connections repairs a small leak. By the time a leak becomes large, sealing surfaces usually are worn and major repairs are needed.

Boiler Operation must focus on 'prevention' to be an effective tool. Whether safety, cost, reliable operation, or all of these motivates such program, it is the best means of preventing common, boiler-related problems.

Fuel Burning

Poor combustion is unsafe and costly. Changes in combustion air temperature and barometric pressure, for example, impact burner performance (see table). Low excess air levels result in incomplete combustion, soot blowing, and wasted fuel. High excess air levels raise stack temperatures and reduce boiler efficiency. Maintaining steady excess air levels with oxygen trim system helps ensure optimum efficiency at all times.

Visually inspecting combustion is the easiest way to detect changes that affect safety and efficiency. Changes in flame shape, color, and sound are among early indicators of potential combustion-related problems. Changes may be due to:

- Large fluctuations in ambient temperatures
- Changes in fuel temperature, pressure, heating value, or viscosity
- Linkage movement dirty or worn nozzle
- Dirty or distorted diffuser dirty fan
- Dirt on the boiler fireside
- Furnace refractory damage.

Visual combustion inspection should be compared to flame characteristics observed at similar firing rates with efficient combustion. However, combustion efficiency is verifiable only with a flue gas analyzer. Even if a flame appears to be good, it should be checked with an analyzer and adjusted once a month.

Before initially lighting any type of fuel and before re-lighting what has been extinguished due to some cause, always scavenge the entire fire side of a boiler at an air flow not less than 50% percent of the normal full load air flow for a sufficient period and displace furnace volume three times by fresh air. This will ensure that all combustible gases are removed from the boiler setting. In any case the period of purging combustible gases should not be less than five minutes. Failure to observe the above precaution may lead to flareback or explosion.

Do not operate the boiler at excessively low rates as incomplete combustion and offensive smoke may result.

Avoid firing at very high rates, as damage is likely to occur to the boilers, and the resultant incomplete combustion will give rise to black smoke and fly ash etc., which may be a nuisance to the surrounding locality.

Solid Fuel

Ignite fuel with live coals from the adjacent furnace or use light combustibles such as wood or rags. Do not use excessively volatile material, which would form an explosive mixture. When fuel is hand fired, feed the fuel little and often and make use of over fire air carefully to prevent the formation of smoke. After the fuel is charged, admit overtire air and then reduce it progressively. Before cleaning the fire, a good bed of hot fuel should be allowed to build up, and one-half of the fuel barred over to one side. The clinker, ashes etc., may then be removed after which green fuel is fired on the bare bars. Red-hot fuel should then be barred over to the freshly fired fuel, and then the process repeated for cleaning the other side of the fire.

Pulverised Fuel

Clean the burner of fuel incrustation, which may block the free flow of fuel and air to furnace. Check the burner box to ensure that all tube protector blocks are in place, so as to prevent any abrasive action on tubes. Establish a proper airflow through the furnace. The burner register should be throttled to improve flame stability. Open fuel feed to a steady minimum rate, ignite fuel and cut down to safe operating value. Invariably light each burner with a hand torch or special ignition equipment. If the minimum stable firing rate is too high to meet the steam demand, do not reduce the firing rate but have recourse to intermittent firing at the minimum rate.

Pulverizing fuel equipment should be inspected for wear and tear. Worn out parts must be replaced in good time to ensure efficient operation.

Oil Firing

Inspect and clean oil strainer, burner tips and check and adjust air registers and oil valves. If steam is not available to preheat oil, make use of an electric heater or any other heating device. Remove spilled oil, if any, from burners, boiler fronts, and furnace floor. Check draft and ascertain that the furnace is properly ventilated as stated above. Switch on oil and light one burner with a torch or other ignition contrivance by placing the torch near and just under the burner tip. If the oil spray does not ignite immediately i.e., five seconds after the valve is opened, or if the torch extinguishes before oil is lighted, remove torch, shut off oil and ventilate the lighting procedure. Stand clear of burners to avoid injury in case of back firing. Always use a torch or other ignition device for lighting burners. Do not attempt to light a burner from a hot furnace refractory, or from an adjacent operating burner. Make sure that there is an excessive draft before lighting additional burners. Do not allow oil to impinge excessively on brickwork or parts of the boiler. After igniting oil, the air register should be opened immediately to prevent incomplete combustion. Never throttle any oil valve beyond the least pressure serving any group of burners. Avoid operation at overrated capacity, since this will increase fouling of boiler and superheater surfaces.

A number of boilers are equipped with fully automatic burner controls. Such controls incorporate many safety features, or ensure safe operation.

Whenever automatic controls fail due to some reason, the attendant must switch over to manual control. An attendant must study carefully, automatic controls as well as manual functions. Automatic controls are not automatic in maintenance, and their upkeep must be carefully attended to. It cannot be overemphasized that automatic controls are not a complete substitute for supervision, and that vigilance according to the conditions of working must be regarded as a pertinent rudiment of operation.
The oil pump must be dismantled and the components checked for wear and tear, clearance, deformation, corrosion and erosion. A large increase in wearing ring clearance is the cause for inefficiency and the manufacturer's instructions must be followed for replacements

Gaseous Fuels

Check the burner, control valves and safety cut outs to ensure that they are in good working condition before lighting up. Purge air out of gas lines through vents before trying to light a burner. Check furnace draft devices and ascertain if proper furnace ventilation exists as stated above. Light the burner, setting it at a minimum rate, using a torch or other suitable ignition contrivance. Do not attempt to light one burner from an adjacent operating burner or from hot furnace refractory. Maintain fuel air ratio so as to always obtain complete combustion.

It should be remembered that generally in gaseous fuels, CO_2 content does not necessarily mean a certain quantum of excess air, and the burners must be operated with sufficient air to ensure complete combustion. Never throttle a valve beyond the pressure serving any group of burners or any individual burner.

If flame failure device of either the photoelectric or conductivity types is provided, test them with a hand torch before relying on them to protect any operating burner.

Equipment for gaseous fuels is generally not subjected to wear and tear. In any case the valves must be examined and attended to for tight shutoff. Malfunctioning of burners is due to burned burner tips and cracked or fouled burners.

Water Level:

A very important rule in the safe operation of boilers is to keep water in the boiler at the proper level an as steady as the circumstances permit. Never keep full reliance upon automatic alarms or feed water regulators. At frequent intervals compare the readings of the several methods of determining water level. The water gauge cocks must be kept in good working condition, without leaking, and these will be kept in good order by frequently blowing through. Blow through the drain cock at the bottom of the gauge and shut and open the steam and water cocks every few hours. These cocks must be blown through more frequently when the water is dirty, and foaming, priming or other feed water troubles occur. Should either of the passage become choked, or whenever the water in the gauge glass moves sluggishly,

the passage must be cleaned. Always test the glass water gauge thoroughly when charge of the boiler is taken. This should be done by first opening the drain cock and then shutting the upper cock, which should give water; the upper cock should then be opened and the bottom closed which should give steam. If water and steam do not appear in proper order, the choked cocks and the passage water cock should be reopened after the steam cock. Have the water column well illuminated and keep the glass clear.

When the level of water disappears in the water glass, blow down the gage glass to determine whether the existing level of water is above or below the water glass. If the water level is below the water glass, stop the supply of air and fuel; close the dampers and ash pit doors. Restart the fire and feed water supply after the entire situation is under control and one is positively certain that if it is safer to continue steaming the boiler.

If low water is caused by operating conditions, rectify it immediately before resuming normal steaming conditions. Low water is one of the most serious emergencies to arise in the boiler room. Low water may be caused by failure of the feed pumps, leaks in feed discharge line, economiser tubes, defective check valves, low water in feed tanks etc. A frequent cause of low water is in attention on the part of the watch or diversion of their attention to other duties. It need not be overemphasized that low water is extremely damaging to the boiler and may jeopardize lives and property. If any doubt exists, continue the feed water supply, do not open the safety valves, or alter the position of the steam outlet valves, or make any adjustment that will cause a sudden change in the stresses on the boiler. If it is ascertained that the water has disappeared in the gage glass, shut out the fuel supply in the case of hand-fired boilers, do not disturb the fire except to cover it with ash or other incombustible material, which would smother the fire. Lift the safety valves by hand to gradually relieve the boiler pressure, close stop valves and other auxiliary valves. Never attempt to lift the safety valve in the event of a high water level. The water gage glass looks the same when empty or full. Ordinarily droplets of condensate forming and flowing slowly down the inside of the glass indicate an empty glass and the absence of the condensate indicates a full glass.

In the case of high water in a boiler, reduce the feed water flow slightly below the steam rate and blow down to lower the water to a safe operating level.

If the superheater temperature shows a sudden drop, it indicates that water is carried over into the superheater, and in this case the fuel must be shut off, blow down water to lower level, feed the boiler with fresh water, blow down again if required and then put the boiler back in service.

The magnitude of losses caused by carry over is many times considerable. Fuel consumption, equipment maintenance costs, and plant safety are afflicted. Solid deposits in superheater tubes affect heat transfer and cause overheating of tubes. Deposits in turbine nozzles and blading interfere with steam distribution and cause high steam rates, and in some instance result in

imbalance and vibration. Incrustation of governing and emergency valves would cause erratic control, over speeding and damage to the machine. Steam pipes may explode due to water hammer, trap trouble from deposits may occur, asbestos or other packing and gaskets may deteriorate due to abrasion, and chemical changes, erosion and incrustation of valves including leakages may occur.

Unusual fluctuations in the water level must be checked and the cause determined. If any unusual or serious foaming occurs as indicated by a fluctuation of water level or sudden drop in superheater temperature, reduce steaming rates until the water level in the gage glass stabilizes adequately, so that the true level of water can be ascertained. If the level of the water is sufficiently high, blow down some water and feed fresh water in the boiler. Resort to alternate blowing down and feeding several times and if the foaming does not stop, bank it fire and continue blowing down and feeding. After correcting the water condition, test safety valves and the connections to pressure gauge and the water column for any sticking or choking. Blow out pressure gauge and water column gage glass drains.

Look for any signs of oil in water glasses, surface blow down and feed water heaters. If oil is found, shut down the boiler as soon as possible and clean the boiler thoroughly.

If the amount of oil or grease is large, boil out the boiler. Find out the source of oil pollution and set it right before putting the boiler back into service. Oil or grease prevents free transmission of heat and leads to overheating with consequent bulging, distortion, rupturing etc.

Priming, Foaming and Carryover:

The causes of fluctuations of water in the drum could be attributed to foaming due to high concentration of dissolved solids, appearing as soap like material. Repeated blowing and feeding may stop foaming. Due to foaming, carryover may result with consequent sudden and steep drop in steam temperature, and in such cases the boiler must be shut down. Before starting up, the pressure gauge, safety valves, and water gauge connections must be checked and cleaned.

The bad effects of oil in water cannot be overemphasized. The presence of oil could be attributed to the condensate return from fuel oil heaters, or form the turbine gland steam exhaust system. By any chance if oil is found present, the boiler must be shut down, the source of contamination determined, and the boiler boiled out before putting it into service.

To maintain the concentration of dissolved solids within the prescribed limits, the boiler must be blown down as and when required. Water wall drains must never be opened when the boiler is in service. Such drain valves should be opened when the boiler is banked or the fire killed.

Carryover results in deposits in superheaters and turbine blades, and this term applies to all contamination in the gaseous, liquid or solid phase of boiler water by steam. Carryover cannot be completely eliminated, but must be

limited to permissible limits by mechanical separators in the boiler drum. Carryover is the result of priming or foaming.

Priming is the result of spouting or surging of boiler water into the steam outlet; thus excessive moisture develops in steam. Too high water level, sudden swelling in drum level on drop in pressure, or sudden increase in loading may cause priming. Water thus entrained in steam may cause a sudden drop in superheat temperature, shocks and water hammer in steam lines, and possible stripping of turbine blades. Priming could be controlled by checked drum internal for proper installation and careful regulation of water level in the drum.

Foaming is caused when water films around the steam bubble liberated from boiler water are stabilized by the dissolved impurities. The effects of foam carryover are similar to that of priming, but less severe in intensity. Such foam carryover depends on the amount of impurities present in water and is difficult to control by mechanical methods. Foaming could be controlled by reducing boiler water concentration, by a controlled continuous blow down system and proper control of chemicals added to boiler water like lignins and tannins in low-pressure boilers. The degree of contamination can be ascertained by measuring the electrical conductivity of the condensed steam.

Water Hammer:

No matter how well designed a steam range may be, faulty operation or neglect in maintenance may result in pockets of condensate, with the risk of explosion from water hammer.
A frequent cause of water in steam pipes is from the priming of boilers due to impurities in the boiler water, or by unsteady load condition. Another cause of the trouble is failure of steam traps due to dirt.
The shock caused by the impact of a mass of water traveling at high velocity results in a breakdown. This is known as water hammer. When steam comes into contact with water at a lower temperature, condensation takes place and a vacuum is formed which would cause the water in the pipe to acquire a very high velocity and strikes a blow, like that of a sledge hammer on the pipe, valve or fitting. This may be caused by direct admission of steam to pipes containing water, by draining pipes containing condensate in the presence of steam, by slow accumulation of condensate eventually causing some alteration to the pressure in pipes containing steam, by formation of steam in feed water heaters or economisers from water under pressure, by formation of steam from heated water due to local increase in velocity resulting in a reduction in the static head pressure.
Before opening a drain tap when condensate is present, shut the stop valve fitted on the steam line. After draining the condensate from a pipeline, ease the stop valve slightly to warm the pipes after which the stop valve may be gradually fully opened, and then the drain closed. Automatic drains are likely to go out of order due to dirt or other mechanical causes, and they must be frequently overhauled and tested to ensure that they are in good working order. A defective trap may be a great source of danger. A good design of

pipes and traps will not allow condensate to accumulate. All pipes must be lagged efficiently.

Water Gauges:

All water gauges must be tested by the boiler attendants directly responsible for the operation of the boilers at the beginning of each shift. For high pressure boiler manufacturers may be consulted, as excessive testing of gauge may result in shorter life and high maintenance cost.

Keep the water gauges and their connections free from leaks and no connections allowing a flow of water or steam from the piping between the water column and the boiler should be made. Any leaks or flow of water or steam will cause a false indication of the water level in the boiler.

The outlet of the discharge pipes from water gauges should be kept open and terminated at a safe point visible and audible to the boiler attendant while blowing down.

Water gauges must be well lighted and maintained cleanly. A gage glass guard must always be kept in position to protect the boiler attendants from injury if the glass breaks. Keep a spare glass handy in the boiler room to replace in case the one attached to the boiler breaks. When a glass breaks, shut off the water valve first and then the steam valve.

Pressure Gauges:

Compare boiler steam pressure gauge frequently to check its accuracy. When the safety valve blows, note the reading of the pressure gauge. If the reading does not tally with the stipulated pressure, or with the gauge on adjacent boilers operating under the same pressure, test the gauges. When the foaming, priming and other feed water troubles occur and are likely to cause choking of the gauge connections, test the gauges. A steam gauge is considered with a dead weight testing device. Such a device is available is the Chief Boiler Inspector's Office and free service is given for testing of pressure gauges.

Never admit steam directly into the pressure gauges and ascertain that at all times the siphon is filled with water. If the steam has entered the gauge, it must be retested. After the gauge is tested treat it with care.

Keep the gauge well lighted and the dial and glass cover in clean condition. A red line must be drawn on the dial showing the highest pressure allowed for the boiler.

Safety Valves:

Maintain safety valves free and in working order. Test the safety valves by raising the valve to its open position by the lever, and allow it to be closed as if it had opened automatically. At least once a year the valves should be tested by raising the steam pressure to their popping pressure.

When the safety valve sticks or fails to operate at the stipulated popping pressure, no attempt should be made to free it by striking the body or other

parts of the valve. Rather, it must be opened with the lifting lever, after which the pressure should be raised to the pressure for which the valve is set to blow. If the valve does not pop, the boiler must be taken out of service and the valve cleaned and attended to.

Do not try to stop leakages by tightening the spring or by obstructing it in any manner whatsoever. When the safety valve leaks at a pressure less than at which it is set to close, try to free the valve by operating the lifting lever. If this does not stop the leakage, repair or replace the safety valve as soon as possible.

Whenever a safety valve blows, observe the pressure indicated by the boiler pressure gauge and if it is different test the gauge. If the gauge is correct adjust the safety valve.

Do not permit safety valves to be adjusted by anyone but an authorized person familiar with the construction and operation of safety valves. Test a safety valve after any setting or adjusting of the spring. Do not have the water in the boiler above the highest level when setting or adjusting a safety valve. When the spring becomes weak and is required to be screwed down to secure the stipulated popping pressure, do not screw down the spring so far that there is a restriction of the proper amount of opening of the valve.

Never set the popping pressure of a safety valve above the pressure stipulated by a competent authority.

When boilers of different working pressures are connected to a common steam pipe and operate under the same working pressure, never set a safety valve to pop at a pressure greater than that allowed for the boiler having the lowest pressure.

Scale, dirt or other foreign matter between the coils of the safety valve springs must not be allowed to accumulate.

The drains in the safety valve body and discharge pipes should be kept open. If the safety valve pops, a boiler attendant must observe the drains in order to determine that the passages are free.

Keep proper tension in all supports and anchors; especially those to which the escape pipes are attached.

When preparing for a hydraulic test above the working pressure of the safety valve, remove it and blank the openings, or clamp the valve securely to the seat.

Blow off valves:

Keep blow off valves and cocks in good working condition, and repair leaky blow off valves as soon as possible. Make sure that they are in good working condition before putting a boiler in service, and examine them carefully when the boiler is not in service. Maintain in good condition the pipe and fittings between the blow off valve and the boiler and inspect them when the boiler is under cleaning or inspection.

Operate blow off valves or cocks gradually and with care. When a blow off valve is shut, see that it is closed tight.

A boiler attendant must never blow down more than one boiler at a time. When blowing down a boiler, pay attention solely to it, and perform no other duty until the blow off valve is closed. When a boiler attendant blowing down a boiler cannot see the water glass, another man must be deputed to watch the water glass, and he should signal the operator blowing down the boiler.

Examine carefully the conditions of the particular plant in order to find out the amount and frequency of blowing down which depends upon the number of hours the boiler is required for service in a day, the rate at which the boiler is operated and the kind of feed water used. Blow down a boiler at least one full opening and closing of the blow off valve every twenty-four hours. Blow down valves on economisers, water cooled furnace walls, water wall boxes, etc., are provided as drain valves and such valves should never be used for blowing down in the usual sense while the boiler is in active steaming condition, except under conditions specially recommended by the manufacturers.

Blow down the boiler if necessary just before putting it into service. When a boiler is in service, see that the blowing down is down at a time when the generation of steam is at the minimum. If any unusual or serious foaming occurs, the fuel and air supply must be reduced, the superheater vents and drains opened and the steam outlet closed, until the true level of the water in the gage glass is determined.

If the level of the water in the glass is high, alternately blow down some of the water and feed in fresh water several times. If the foaming does not stop, bank the fire and resort to alternate blowing down and feeding. Check boiler water chemical concentrations and feed water for pollution. If this cannot be corrected, immediately reduce load until a stable water level is obtained, or remove the boiler from service and if necessary inspect the circulators and baffles, and correct their positions.

Dampers:

Dampers should be maintained in good working order. Inspect and repair them before starting a boiler. Check them at certain intervals when the boiler is in service, and certainly at the same time of its periodical or statutory inspection. Electric interlocks operating through automatic combustion control on forced and induced draft dampers, permitting operation of dampers upon loss of fans or loss of fuel, should be tested immediately before putting the boiler in service from either a cold or banked condition. Boilers with natural draft should be provided with counter weights on the dampers, which could be operated preferably from the boiler front ends.

Soot Blowers:

External cleanliness of the boiler, superheater, reheater, economiser and air heater surface has direct bearing on efficiency, capacity, and draft loss. The frequency of cleaning depends upon the quality of fuel used, load conditions,

disposition of the equipment and steam temperature. Dry and saturated steam and compressed air are used for soot removal. If lancing is used, compressed air is preferred. While hand lancing a steam boiler, particular care should be taken to ensure sufficient negative furnace pressure to protect those doing the lancing operation. If water lancing is employed, direct impingement of water on tubes, headers or drums must be avoided to prevent thermal quench cracking.

It is desirable to increase the furnace draft above normal when operating soot blowers or to change over to manual operation during the blowing period. Before operating blowers, its pipeline should be thoroughly drained.

Compressed air is preferable for the cleaning operation when the units are not in service, as steam may cause external corrosion.

When the rotating type of soot blowers are installed, the nozzles must be maintained in proper position relative to the tubes. If they become displaced, serious erosion of tube metal and consequent failure can result. When retractable blowers are installed, the operation should be carefully watched to prevent damage to the blowing elements in case they do not retract properly.

Portable steam lances can also cause wasting of tubes if directed upon the same location for long periods. Soot blowers should be carefully examined at the time of each internal inspection and faults if any corrected.

Operating procedures for Soot Blowers:

a) Assure that power is available at the proper voltage and frequency as specified on the application drawings.

b) Increase the furnace draft.

c) For steam blowing systems, open all drain valves wide. If traps are used, be sure isolation valves are open and the by-pass valve is closed.

d) Open the steam or air supply valve slowly until it is wide open. Do not operate at any blowers until all the piping have been warmed and drained. Then, if traps are not used, close the drain valve. The hole in the valve seat will serve to keep the lines drained. Never blow with wet steam.

e) Operate the blowers in the numerical sequence shown on the general arrangement drawing. There is a panel with “start” push button for each blower. The buttons may be included in the automatic sequential operation or they may be individual (buttons for manual operation) therefore one button must be used to start each blower. Each button should be held in about 5 seconds and then released. The blower will start operating; complete the cycle and this will be indicated in the panel. Start the next blower after this blower operation is over.

f) When the entire blowing cycle is complete, close the main stop valve tightly. Open the drain valves wide if they are closed.

g) Adjust the furnace draft to normal.

h) Open the power and control circuits.

i) Be sure all blowers have completely retracted and all heads are fully closed.

Supports:

When structure, surrounding boilers are designed and equipped for expansion of the boilers, they should be inspected at regular intervals in order to maintain the full amount of clearance provided. Settlement of boiler foundation must also be checked. Any structure over the boilers or supporting columns between them must be examined and maintained in good order.

Pipeline supports and brackets should be examined at regular intervals and as far as possible maintained under their average stress. Rollers in pipeline supports shall be maintained in position and free for movement.

When chimneys are mounted on structures directly above boilers, or upon the boilers themselves, precautions should be taken to maintain in good condition all safeguards provided for the protection of all steelwork against corrosion caused by moisture or water at such places running down on the chimney or from the roof.

Supports of blow off pipes must be maintained in satisfactory condition and alignment.

Brickwork Drying:

Regarding brickwork of a new boiler or extensive refractory repairs carried out on an installed boiler, drying out of the brickwork and insulation must be carried out with a slow fire without generating steam pressure for a period of say three to seven days, depending on the prevailing conditions. Such drying out may not be necessary in boilers of radiant type where there is very little furnace refractory. The manufacturer's instructions for drying out by solid, or liquid fuel must be followed. Temperature rise in the refractory should be limited to 10ºC (50ºF) per hour. After the drying process is completed, boiler casings for infiltration of air under pressure by means of smoke cartridges or wet straw must be checked.

Boiling Out:

After the refractory in the boiler furnace is dried out, boiling out of pressure parts must be attended to. Generally a dilute solution of tri-sodium phosphate or soda ash is used for removal of mill scale, grease, oil, etc. Boiling out must be carried out as suggested by the manufacturers and under the supervision of an expert in the field. The boiling out process could be completed in about three days. The maximum boiling out pressure on the third day should be about fifty percent of the normal working pressure of the boiler. The main steam pipe range could be warmed up during such periods and drain valves opened to clear the sediment. Steam traps could be bypassed during the boiling out process. Superheater and steam pipes should be blown through to ensure that all foreign material is removed.

After boiling out is completed, hand and manhole covers should be removed for internal inspection. Loose mill scale sludge and similar deposits should be

cleared and the headers cleaned with water jets. All blow down and drain valves should be washed through to ascertain that their passages are clear. Gauge glass and pressure gauge connections may become dirty during the boiling out process and should be thoroughly cleaned.

Shutting down a boiler:

When shutting down a boiler, the firing rate and draught conditions should be reduced as recommended by the manufacturers simultaneously with the steam flow. After the lower limit of the control range is reached, manual operated should be adopted. Economiser recirculation valves where provided should be opened soon after the boiler is shut down or before changing over form continuous to intermittent feeding.

Pulverisers should be taken out after running them empty, which must be progressively down, the last to be taken out of service being nearer the boiler entry. At the prescribed minimum lead, oil support and igniters should be used. As the pulverisers empty out it would be necessary to have its igniters in operation to prevent flame instability.

In stoker-fired boilers the stoker hopper should be run empty and fuel permitted to burn out before the boiler is taken out of service.

The expansion movement of the boiler should be checked at regular intervals as the load is reduced. If the boiler is connected to a common steam range, the stem of the non-return valve should be run down and then the range side valves closed. Where two stop valves re provided, the range side valve should be closed after the boiler side valve is shut off. The shut off valves may be cheeked for tightness by opening the drain valve between them.

The furnace must be cooled steadily and the forced draught fan continued in service to purge the boiler for about thirty minutes after the fire is killed. Where refractory work is extensive, the boiler must be cooled sufficiently, before airflow is increased for rapid cooling.

After the fire is killed, the boiler may be fed with water to three quarters in the gauge glass and then feeding stopped. The feed pump should be kept running in case of controlled circulation boilers.

When drum pressure drops to 1.75 kg/cm^2 (25 psi), drum vents should be opened to prevent formation of vacuum to prevent leakages at the gasket joints.

After the boiler has sufficiently cooled, soot blowing or dusting may be carried out keeping the airflow as high as possible. Soot blowing when the furnace is hot may cause flue gas explosion.

Before commencing the work for boiler cleaning etc., all feed and steam valves must be shut tight and locked. Pulveriser and fan breakers should be de-energised. Oil and atomizing steam supply valves should be closed and oil gun removed from burner housing. Gas supply valves, where provided, must be closed. It is advisable to blank the supply line and thoroughly purge the gas line towards the boiler beyond the blank with inert gas or steam, before

commencing work into the boiler furnace. Neglect of the above precautions may lead to serious or fatal accidents.

For internal inspection or cleaning, manhole covers of mud drums must be opened last after the cover of the top drum is knocked in first. If the process of opening the covers is reversed, there is a likelihood of injury to personnel due to escaping steam or hot air caused by suction action.

If external surfaces are to be washed by steam or water, this should be carried out just before the boiler is put back in service, so that the water, which accumulates in pockets, crevices, porous refractory, or other such places, may cause corrosion, if permitted to remain. After water washing, if the boiler cannot be put in service, the boiler must be fired to dry out the moisture. Specially in oil fired boilers, water must not be permitted to remain after water washing, as the oil deposits may absorb moisture and cause corrosion, and hence the boiler must be fired for a short period to dry out the tubes and setting.

Preservation of boiler when not in use:

Steam Boilers when not in use are liable to deterioration from corrosion. Unless well cared for and made rust proof, they may depreciate more rapidly than when in use.

Wet storage:

If the boilers are required to be kept out of service, but are likely to be required as standby units, the wet method is a practical one, by which a unit could be made ready for service. In the wet method, the boiler is filled through the economiser with deaerated treated water to give the required alkalinity, and the boiler is fired with low sulphur fuel, and steamed in service so that the boiler water will be circulated to secure uniform concentration throughout the unit, and the oxygen eliminated from the water. The boiler load should then be reduced slowly and the water level raised as high in the gauge glass as its consistent with safe operation, while delivery some steam a concentration of 100 ppm of hydrazine should be maintained for preventing oxygen corrosion. When air cocks reveal no pressure in the boiler, and before a vacuum can be produced, the boiler should be filled in by deaerated water, until water spills over and fills the superheater using a high point air vent, such as pressure gauge connection as an indicator. The drum air cock should be connected to a surge tank located above the steam drum to ensure positive pressure and prevent ingress of air to the boiler, thus compensating for volumetric changes due to temperature.

After firing the boiler, the setting should be closed and maintained in a closed condition. Periodical inspections may be carried out to observe if condensation has occurred on external surfaces, and if this happens, heating devices may be placed at convenient points to keep metal surfaces above dew point. In wet storage, the boiler must be protected from frost. If the ambient temperature is likely to be dropped to freezing point, this type of storage must be avoided.

A protective coating should be applied to auxiliary equipment. All moving parts should be rotated once in a week and also electrical equipment attended to. Oil lubricated bearings should also be attended to as suggested by the manufacturers for the equipment not in use. Generally gearboxes and such applications are drained and cleaned, and filled with medium viscosity oil excluding air.

Boiler connections should be checked for leakages and water samples analyzed. If hydrazine concentration has dropped below 50 ppm, chemicals should be injected to bring the concentration to normal after lowering the level. The boiler should then be steamed sufficiently to circulate the water added with chemical and the procedure followed as stated above. In any case, if the boiler is to be stored for unduly long periods, it should be emptied and inspected for corrosion defects.

Dry storage:

For dry storage the boiler must be cleaned properly and dried thoroughly, since the moisture may cause corrosion of metal surfaces. Precaution must be taken to prevent entry of moisture in any form, from steam, feed and air lines. For this intent moisture assimilating material such as quick lime at the rate of 0.9 kg (2 lb) or silica gel at the rate of 4.5 kg (10 lb) for 4546 litres (1,000 gallons) capacity, should be placed on trays inside the boiler shells or drums to absorb moisture from the air. The manholes should then be closed and all connections on boilers tightly banked. The serviceability of the materials for such purposes and their replacement may be judged through regular internal boiler inspections. Alternatively, dried air may be circulated through the boiler.

Operational Aspects of Superheaters and Reheaters:

The following points must be taken care of to ensure longer life and higher availability of the pressure parts:

a) The metal temperature at all the locations should be kept within permissible value. This can be accomplished by keeping the steam temperature at the end of each section within a particular value. Desuperheaters are used to maintain the steam temperature and this will serve for the metal temperature restriction also except at primary superheater outlet before which there is no desuperheater. During design stage sufficient margin is kept between the permissible temperature and predicted temperature to take care of most of the operating conditions. However, operating the boiler with low feed water temperature along with high excess air may result in exceeding the limit. There should be no hesitation to bring down the load on the boiler if this temperature cannot be brought under control by other means. Tilting the burners down, operating the lower tier burners, soot blowing the water walls, reducing excess air, raising the feed water temperature will help reducing the heat pick-up in superheaters.

b) The raising and lowering of steam parameters should be restricted to the value given in the starting diagram. Exceeding these values will result in reduced fatigue life of pressure parts.

c) The superheaters and reheaters are to be soot blow down to keep them reasonably clean. Indian coals have high silica content and hence no problem is faced in keeping the surface clean.

d) In the case of tube failure which can be identified by hearing the noise in the boiler gallery and cross checked by difference in steam and water flow, gas and steam temperature, the boiler should be shut down at the earliest by regular procedure for maintenance work, otherwise large number of tubes may fail due to steam erosion and impingement.

e) Drum level should be maintained at recommended level both during starting and at all conditions of operation to avoid carry over and in extreme cases flooding of superheaters.

f) Entry of wet steam into superheater first rows or after desuperheaters will result in removal of the oxide film due to thermal shock. Boiler salt in the steam will accelerate the corrosion. Austenitic steel is the worst affected due to stress corrosion in this case. Hence the temperature after the desuperheater should be maintained well above the saturation point in the case of direct spray type.

g) Reheater starvation should be prevented at all conditions of operation. During starting till sufficient flow through the reheater is established, furnace exit gas temperature should be kept below 540`C. During emergency shut down or turbine trip fire should be put off automatically by operating master fuel trip if flow through reheater cannot be established automatically by-pass station (if provided).

h) The reheater temperature can be controlled normally by the method provided for. However the desuperheater has to be kept as a ready stand-by to meet emergencies, but passing of regulating valve of water injection should be avoided by keeping the isolating valve in closed position.

i) The flue gas and steam temperature difference between left and right should be minimized to the extent possible by adjusting the burner loading, location and loading of left and right side of draft fans.

Operation of Economisers:

Before starting up the boiler, economizer should be inspected and cleared of foreign materials, if any. Alignment of coils and the supporting arrangements are to be periodically inspected. All access doors should be bolted tightly. Check the doors occasionally for tightness.

It is essential to see that the inside corrosion of pressure parts including economizer is prevented by better water chemistry. Presence of dissolved Oxygen in water and low PH may cause corrosion to tube material. Hence deaerated water is always to be used as boiler feed. PH of feed water should always be more than 8. Otherwise the tube metal will become susceptible for low PH corrosion. If external steam is available make use of the deaerating

facility and fill up boiler only with oxygen free water. Feed water temperature must also be maintained at the highest possible level either with the help of feed water heaters or heating the water in feed tank. Low feed water temperature (obtained during low load operation) will result in external corrosion of economizer.

Some of the large capacity boilers are provided with recirculation system as a save guard arrangement to economizer. At the time of start up of boiler at times the feed flow may have to be closed completely, as there will be swelling of level in boiler drum. But if the economizer is starved of water flow the tubes may get over heated and result in tube failures. Hence the economizer circulation system should be kept open, when there is fire in the boiler with no feed flow. The unbalance in gas flow between different paths will result in different water outlet temperature from economizer and hence gas flow has to be equalized. Steaming in economizer is harmful to economizer unless otherwise it is designed as steaming type and hence steaming should be prevented by keeping a watch on economizer outlet water temperature. To prevent steaming, during design stage, sufficient margin is kept between the predicted economizer outlet water temperature and saturation temperature for the corresponding pressure.

Frequency of operation of soot blowers depends entirely on local conditions. Close watch on draft loss between consecutive blowing will determine the frequency of soot blower operation. In many cases it has been found that blowing the economizer soot blowers once a day or less is sufficient.

Operational Aspects of Fans:

In modern installations, boiler control has provision for remote 'manual' as well as 'automatic' controls from the Control Desk. Of course the conditions of the fan and the control parameters are all displayed in real time with the help of on line indicators. However the following essential checks need to be carried out physically at fan locations for ensuring safeguard of the equipment.

Before starting any fan:

a) Check for bearing lubrication. Check for oil level in bearings. If forced lubrication is provided check for normal operation of the lube oil pumps. Verify the lube oil pressure and the temperature nearer to the bearing location. Check whether the cooling circuits for oil coolers are through and the oil level in oil tank is normal,

b) Rotate fan by hand and verify that the shaft is mechanically free to rotate,

c) Ensure that the direction of rotation of drive motor is correct, if any work on cable connection had been done prior to starting,

d) Check the remote/interlock operation of dampers and regulating vanes. Check for proper open and close position of the dampers,

e) Ensure tightness of foundation bolts, manholes etc. and

f) Check the motor and cooling system as per the respective manufacturer's instructions.

Ensure that the fan is always started with minimum loading. This can be achieved by ensuring that the inlet and outlet dampers in close position and the regulating vane is kept in minimum position, before starting the fan. The fan can be loaded, when the drive reaches its rated speed if there is no abnormal noise or vibration in the fan.

During normal running of the fan:
a) Lubricate at regular interval.
b) Check up lubrication and cooling system.
c) Have a watch on bearing temperature.
d) Check up for abnormal noise and vibration.

Immediate attention is to be drawn to stop the fan and carry out investigation, if there is abnormal raise of bearing temperature conditions or there is abnormal or excessive vibration. The cause of vibration should be analyzed and established. Rectification act should to follow immediately. If insitu site balancing is required it has to be done under supervision of experts. In the case of worn out impeller, the control equipment position will reach maximum for the same conditions of operation. In these circumstances it is essential to stop the fan to attend to the defect; otherwise it may lead to forced shutdown for longer period due to damage to other associate equipment also.

Boiler Log:

A Boiler Log is a checklist for the Boiler Operators. It helps to track the operating parameters over a period. For any Boiler Preventive Maintenance the Boiler log is a key factor. Separate log sheets are required for each Boiler in the plant. One option is having a log sheet that is valid for one month (31 days), and has provision for two sets of readings per day for low and medium pressure boiler and three sets of reading per for high pressure boilers. It is recommended that completed logs should be properly preserves for future analysis.

The need for a boiler log:

It helps to avoid an emergency shutdown. Over a period of time, by following operating trends from the boiler log, one can properly diagnose the problems and fix up a suitable system maintenance schedule. For example, a steady rise in stack temperature, at the same boiler load, indicates dirty boiler firesides or waterside scale build-up. In either case preventive measure can be taken before it is necessary to shut the unit down for cleaning.

The majority of the Boiler accidents occur mainly due to two reasons, control failure and human operational / maintenance mistakes. Proper keeping and analysis of boiler logs help operators to avoid operational/maintenance error and therefore reduce boiler accidents. Data in the log should be compared with data recorded when the boiler was new or recently overhauled. If such a

comparison reveals significance deviation, technician may need to inspect and repair components.

Check list to be covered in a boiler log:

Log sheets are available from boiler insurance companies. Maintenance log should include those items recommended in the boiler and burner manufacture's operating instructions. It is always advisable to prepare customised log form. These logs can be easily customised for the particular installation and its unique requirements. Suggested items that might be included in maintenance log are shown below. But items may be added or deleted as needed for the specific installation. It is advisable to maintain two Log Sheets to filled up by the control room and field operators separately.

BOILER MAINTENANCE:

Following are the important objectives to be fulfilled by a boiler:

- It should be safe,
- It should operate to its capacity with efficiency and
- It should have long economical life.

In order to ensure that the above objectives are achieved, it is necessary not only to operate the Boiler in a proper manner but to also maintain it in a condition so that the above objectives are achievable.

If due emphasis is not given to the proper and scientific maintenance of a boiler, it would suffer from frequent unplanned shut downs and breakdowns resulting in production loss and high cost of putting it back into operation after each such unplanned shut down or breakdown. Further, such frequent unplanned stoppages of steam generation shall result in consequential losses in the process where steam is put to use. Also, if a boiler is not maintained properly, its condition can be unsafe and result in accidents causing loss of life and property apart from losses of revenue.

Therefore, modern techniques of maintenance are used for ensuring that the above-enumerated three objectives are achieved. These techniques are the following:

1. **Routine maintenance** - covering such activities as are recommended by manufacturers of various machinery or components of a boiler. For example - topping up lubricant of bearings of fans and fan motors and pumps and pump motors, blowing cocks of level gauges, maintaining cleanliness in and around boiler house, etc.
2. **Preventive maintenance** - covering such activities which are meant for preventing of breakdowns and unplanned shutdowns. For example - tightening the gland of pumps and valves, replacing v-belts after they have been operating for a pre-judged hours based on experience, etc.
3. **Predictive maintenance** - covering such activities that are meant for diagnosing the condition of various parts and components of a boiler and

taking actions in advance so that forced shut downs and breakdowns do not occur. For example, measurement of vibration of bearings of fans and pumps and their respective drive motors and taking action for balancing or other corrective measures in case vibrations are found to be on the high side.

Out of the above three categories of maintenance, the first two are sometimes classified under one common head viz., '**Scheduled Maintenance**'. Thus there remain only two categories of maintenance viz., Scheduled Maintenance and Predictive Maintenance.

Certain maintenance work is also to be taken care of while operating the boiler. The above mentioned three categories of maintenance are over and above those.

Routine Maintenance:

All maintenance work that is to be carried out routinely and is prescribed by respective equipment manufacturers or the boiler manufacturer fall under this category of maintenance. For ensuring that the Scheduled Maintenance is carried out properly it is customary to prepare schedules for all the maintenance activities based on Maintenance Manuals of various original equipment suppliers or the Maintenance Manuals of the Boiler Manufacturer.

The Schedules of Maintenance Activities for automatic package boiler comprise Daily, Weekly, Monthly and Annual Maintenance Activities. Following is an example:

Daily Scheduled Maintenance Activities:

1. Blow off water from the main intermittent blow off valve in every shift for about half a minute to remove sludge and sediment.
2. Blow down water column for every hour; all the water gauge test cocks must be operated to check water level. Float chamber of the alarm device must also be blown.
3. Check water analysis every shift.
4. Check stacks temperature. If it is higher than normal, Check asbestos rope seal in back cover; also check if refractory is damaged. Higher chimney temperature could be attributed to scale formation on internal heating surfaces, or excessive soot formation or carbon deposits on smoke side, and short-circuiting of gases.
5. Check burner block for excessive clinker formation.
6. Check lubrication of moving parts.
7. Check CO_2 for abnormal rise or fall.

Weekly Scheduled Maintenance Activities:

1. Clean burner nozzle with kerosene or compressed air. Such nozzles must not be cleaned with metal wire or cotton waste.
2. Clean burner diffuser plate and check electrode position.

3. Clean lens of photoelectric cell.
4. Clean sight glasses for viewing flame.
5. Clean fuel oil strainers and filters.
6. If necessary, regenerate water softener, which should be on the basis of analysis and not on time schedule.
7. Check the working of low water arrangement and automatic devices if they are in good working order.
8. Clean tubes from fire side.
9. Check water pump operation.

Monthly Scheduled Maintenance Activities:

1. Check electrical automatic equipment and clean contacts if necessary wiping them with clean cloth moistened with carbon tetrachloride. Never use emery or other abrasives to clean the above contacts.
2. Check feed pump gland.
3. Check for clogging in oil lines.
4. Remove and clean all the burner components.
5. Clean blower screen and blades.
6. Test the safety valves if they lift freely at the set pressure.
7. Check tube ends for leakages.

Quarterly Scheduled Maintenance Activities:

1. Open out boiler after cooling it, drain water completely, and open air cock before man and hand hole covers are removed. If the boiler is in battery with others, isolate it thoroughly from others. Also isolate control panel before carrying out maintenance.
2. Clean the boiler internal heating surfaces with high-pressure water hose.
3. Check water surfaces for scale, corrosion etc., to modify water treatment.
4. Check the tube ends for leakages or corrosion.
5. Open chambers of automatic water control equipment, remove float and switch mechanism and other parts, clean and service them if necessary.
6. Replace man and mud hole covers using new gaskets.
7. Replace asbestos ropes fitted to end covers. Repair refractory if necessary.

Half-yearly Scheduled Maintenance Activities:

1. Open all mountings and attend them.
2. Attend to feed, and oil pumps, and other accessories.

Annual Scheduled Maintenance Activities: In addition to daily, weekly, monthly, quarterly and half-yearly maintenance the following annual maintenance may be envisaged:

1. Clean fire and water sides thoroughly and offer boiler for statutory inspection and hydraulic test, after applying to Boiler Inspectorate well in advance.
2. Repair rear and front doors and ducting leading to chimney. Clean the chimney and ducting internally and externally and apply paint.
3. Overhaul all auxiliaries, blowers, fans etc.
4. Overhaul electric motors and test their insulation.
5. Replace refractory and baffles if necessary.
6. Overhaul and clean feed water, oil service tanks, and softening plant vessels.
7. Clean the internal heating surfaces of a boiler by chemical process.

Preventive maintenance:

Preventive maintenance is the most widely used means of minimizing common problems in boilers. Statistics indicate about two-thirds of all boiler failures and nearly all unscheduled shutdowns are caused by poor maintenance and operation.

Boiler inspection and maintenance are critical. A typical inspection schedule covers four basic areas: boiler, burner, controls, and system. Regardless of boiler design, application, or size, the basic maintenance criteria remain the same.

Maintaining the Burner:

Although burners vary by design, application, fuel, regulations, and insurance requirements, the same basic maintenance criteria must be addressed. Burner maintenance generally focuses on safety, efficiency, and reliability. Only a trained service technician using the proper instrumentation and tools should make adjustments.

Fuel and air linkage: Changes in fuel and air linkage affect the combustion fuel-to-air ratio. Flame failure or a hazardous fuel rich condition may result. Proper linkage settings should be physically marked or pinned together. Linkage should be checked for positioning, tightness, and binding. Any noticeable changes should be remedied immediately.

Oil pressure and temperature: Pressure and temperature directly affect the ability of oil to properly atomize and burn completely and efficiently. Changes promote flame failure, fuel-rich combustion, soot blowing, oil buildup in the furnace, and visible stack emissions. Causes include a dirty strainer, worn pump, faulty relief valve, or movement in linkage or pressure-regulating valve set point. Oil temperature changes typically are caused by a dirty heat exchanger or a misadjusted or defective temperature control.

Gas pressure: Gas pressure is critical to proper burner operation and efficient combustion. Irregular pressure leads to flame failure or high amounts of carbon monoxide. It may even cause over or under firing, affecting the

boiler's ability to carry the load. Gas pressure should be constant at steady loads, and should not oscillate during firing rate changes.

Usually, pressure varies between low and high fire. Therefore, readings should be compared to those taken at equivalent firing rates to determine if adjustments are needed or a problem exists. Gas pressure irregularities are typically caused by fluctuations in supply pressure to the boiler regulator or a dirty or defective boiler gas pressure regulator.

Atomizing media pressure: When oil is burned, an atomizing medium, either air or steam, is needed for proper, efficient combustion. Changes in atomizing media pressure cause soot blowing, oil buildup in the furnace, or flame failure. Changes result from a regulator or air compressor problem or a dirty oil nozzle.

Fuel valve closing: If a fuel valve leaks, after burn may occur when the burner is turned off, or raw fuel could leak into a hot boiler and cause an explosion. When the burner is turned off, the flame should extinguish immediately. Prolonged burning is a hazard and demands immediate action.

Maintaining the Controls:

Controls are often used to protect the boiler against unsafe operation. Flame safeguard, operating, limit, and safety interlock controls are among the most common. Of course, controls only protect the boiler if they are maintained and adjusted properly.

Flame safeguard control: Also called the primary control or the programmer, the flame safeguard control ensures safe light off, operation, and shutdown of the burner. The control regulates purging the boiler of all gases prior to trial for ignition. It also verifies that there is no flame in the boiler prior to light off, and checks for a pilot before allowing the main flame to light. The control provides proof that the main flame has ignited before releasing the boiler to the run (modulation) mode. Most importantly it does not allow any action to occur if operating controls, limits, or safety interlocks are open.

In addition, this control initiates a post purge upon shutdown to remove all gases from the boiler. And it often provides a means for detecting a problem elsewhere in the system. Although the flame safeguard is designed for fail-safe operation and is quite reliable, a faulty device can be catastrophic and should not be ignored.

Operating and limit controls: These controls tell the boiler at what temperature and pressure to operate. Proper settings minimize boiler cycling, maintain proper limits for efficient system operation, and ensure the boiler shuts down when predetermined limits are reached.

Improperly set operating controls cause the burner to operate erratically and stress the pressure vessel. All these controls should be checked weekly. The scale of the control for temperature or pressure settings should not be relied upon. Settings should be verified with the actual operating temperatures and pressures on the boiler gauges.

Safety and interlock controls: Safety and interlock controls vary with state, local, and federal codes and insurance requirements. They must be operational at all times. Among the consequences of inoperable safety interlocks are personal injury, equipment or property damage, and liability for losses or damages. All interlocks should be checked weekly for proper operation. A defective control should be replaced immediately. A control should never be bypassed to make a boiler run.

Indicating lights and alarms: Indicating lights and alarms are part of the control circuit. They alert the operator to specific boiler conditions. Unfortunately, they are often neglected and do not provide the intended information. Many control circuits have test buttons to verify proper operation. Simulating conditions that activate a light or alarm should check circuits that do not have such facility.

Maintenance of Superheaters and Reheaters:

When the boiler is shut down and is cool enough to enter and make an external inspection of superheaters and reheaters. Clean the firesides, where necessary, and examine all tubes for evidence of corrosion, erosion, swelling, warping blistering etc.

Swelling of superheater tubes indicates overheating which may have been caused by bringing the boiler up to pressure too quickly, failure to vent the superheater sufficiently during start-up or scale on the internal surface due to carry over. Slight warping is not serious if steps are taken at once to determine and eliminate the cause.

Check the conditions of setting, manhole doors, and casings for leaks and rectify. Remove the hand hole caps if provided and inspect the internal tube surfaces.

If the unit is shut down for considerable time, lay up procedure given in the water treatment chapter has to be followed.

Washing of heating surfaces of superheaters and reheater are seldom required for boilers firing Indian coals. But oil firing may require washing. Washing can be effectively done by using hot water (30 kg/cm^2 and 200`C). In severe cases, caustic or soda ash may be added to water. Care should be taken to arrange draining of the wash water effectively. The air/gas ducts should be blanked to avoid entry of water into air heater, other gas duct, air duct etc. The hoppers should be cleaned of ash before starting the wash. Huge amount of water is needed and complete thorough washing should be attempted to avoid acceleration of corrosion and plugging due to left out soot. Immediately after washing, the surfaces should be dried by firing boiler at low rate.

Most of the Indian coals used for high capacity boilers are having high percentage of ash and the ash is predominantly silica. And hence erosion due to fly ash is inherent and superheater reheaters, economizers are vulnerable for this. Screen tubes, terminal tubes, and bends are to be checked for this erosion. Erosion around the soot blower may also occur due to steam erosion.

Boiler design parameters are based on conservative possibility of erosion. However there is still possibility of localized erosion.

Erosion is indicated by polished surface appearance, gauging, holes in duct expansion joints, etc. Reduction of tube diameter can be verified by micrometer readings. The effect of erosion can be controlled by protecting the affected area (Pad welding, installation of replaceable tube shields, refractory coating etc.) or by dispersing the flue gas stream by the use of deflector plates or wire mesh baffles. But care should be exercised when installing deflectors or baffles so that it will not create new areas of erosion or shift erosion from one area to another.

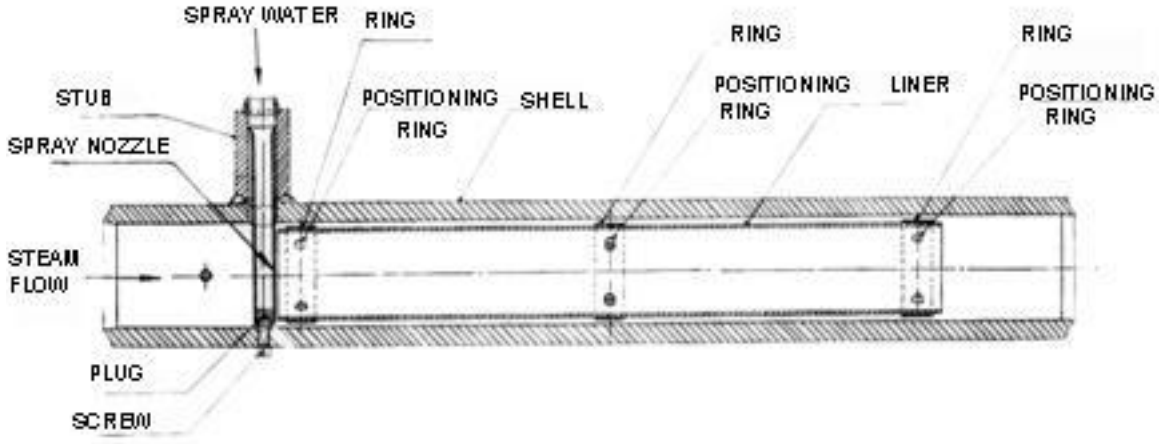
Fuel oil contains contaminants such as Sulfur, Vanadium, and Sodium etc. Hence mainly in oil fired boilers gas side corrosion is experienced. The life of the pressure parts can be increased by providing stainless steel shield in front of first row and by operating at less excess air.

Remnant Life of pressure parts can be easily assessed by non-destructive testing methods available. Ultrasonic thickness gauge can be used to measure the tube thickness, which will reveal external and internal corrosion, erosion and pitting. Radiography can also be utilized. Special camera and scopes are available to see the internal surfaces of the headers and pipes. In extreme cases tubes at suspected points may be cut and subjected for test on Oxide layer thickness measurement and creep strength tested.

Failure of superheaters and reheaters may occur due to various reasons. In a newly commissioned unit the most likely reason is overheating by blockage of foreign material, which may not be traceable after failure if blown out by the failure. Erosion by ash or soot blowers may cause failure if not inspected and rectified in time. Due care is taken during design stage in selecting material and allowance is given for stratification of flue gas and water/steam. Corrosion and pitting on steam side may result in tube failure if feed water and boiler water conditioning are not satisfactory. The failure caused by material defect, material mix-up and welding defect are minimized to a greater extent by tight inspection and quality control methods used currently.

The maintenance of high-pressure parts requires storing of correct material, correct size tube and welding consumables. Highly skilled and qualified welder has to do the hob as per the approved method of the national code and recommended procedure for the particular job. Pre and/or post heat treatment and subsequent inspection and testing are essential to ensure freedom from harmful defects.

Normally spray type desuperheaters are fitted with renewable liners to protect the main superheater shell from erosion of spray water and thermal shock. See figure below. Excessive noise usually indicates the work on liner.



Desuperheater

Whenever a work is carried out on pressure part all precautions should be taken to avoid the entry of foreign material inside the pressure part, as this will cause another failure. Surroundings should be kept clean. Ash, firebrick, dust etc. are also harmful as these contain high silica. Extreme care should be taken in this regard when a work on desuperheater or valves is taken up since the possibility of foreign material entry is much favourable.

Maintenance of Economisers:

With higher feed water temperature now used in modern boilers with pulverized fuel firing low temperature corrosion or bonded deposits in economizer are seldom encountered. For on load cleaning most common arrangement is to provide full retractable or half retractable lance blowers at gas inlet to economizers. Shot cleaning can also be utilized but lance cleaning is normally sufficient.

Water washing can be done to remove bonded deposit and fouling at inaccessible locations as off-loading cleaning. In severe cases soda-ash solution may also be employed. Even though on load cleaning is sufficiently effective, it is usual to water wash economizer during each annual overhauls.

All welded type economizers require little maintenance apart from routine cleaning mentioned above. Experience has shown that site welds are more prone to failure particularly during initial period of operation. The location of these site welds is carefully studied in design stage to afford the best possible access for welders on site. Most reliable site welding method and checking the weld with radiography will ensure higher availability.

Maintenance of Feed Pumps:

Feed pumps should be dismantled, cleaned and reassembled, as recommended by the manufacturer. Where strainers are provided they should be cleaned when the pressure drop exceeds the permissible limits. Before starting a new pump or one after a period of prolonged idleness, bearings should be wetted with lubricating oil, the lubrication system cleaned and filled with fresh oil. The cooling water system where provided should be

checked. The pump should be primed before starting. For hot water service, the pump should be warmed up gradually using the warming up connections provided. Proper suction pressure must be maintained to operate the pump at a specified temperature.

Pump alignment should be checked at operating temperature at regular intervals. Sludge formed in lubricated couplings may adversely affect the flexibility of the coupling. Such couplings should be watched for leakages and oil topped up. Oil should be drained and replenished at certain intervals and at least once in a year.

Cavitation in a centrifugal pump is not very harmful judging only from the noise, unless excessive vibrations are caused. If cavitation is severe, wasting of metal occurs in vanes of the impeller, or enlarged balancing ports, and loss of efficiency is the result.

Dynamic balancing of impeller is necessary for high-speed multistage close clearance pumps. Vibration is caused when a pump is repaired unless the impeller is statically balanced. Vibration not exceeding 2 mils on the bearing house is considered satisfactory for are repaired pump or a new one, when installed on a regular foundation.

Flexible seal parts should be replaced if they are hardened or pitted. Any other parts like metal collars, rings, springs, etc., may be replaced if they are deformed or pitted. All packings must be replaced.

The shaft must be examined for corrosion, worn out key ways, and keys replaced. All parts, which mate with one another, should be measured and compared with original size. If the ball bearings feel rough when turned in hand they must be replaced.

Maintenance of Fans:

Following are the salient points to be taken care of in respect of fans:

a. Procedure recommended by manufacturer is to be followed for disassembly, assembly of impeller, bearing and other works.
b. Use only recommended lubricants for the bearings. Periodic topping up and replacement as per the condition of oil by inspection and analysis is to be done. Follow OEM recommendation and replace oil after the specified running hours of operation is completed.
c. The period between the replacement, check up etc. can be varied from manufacturer’s recommendation by the customer to suit his condition only if he is satisfied that it is not against the safeguard of the equipment.
d. During the planned maintenance, the maintenance personnel should take all the care so that the equipment will perform satisfactorily till the next planned shutdown.
e. During emergency maintenance work, the time will be critical, but quality of the work or safety of personnel and equipment should not be sacrificed.

Maintenance Check-ups

(a) During annual overhauls check up critical clearances of impeller blade and casing/inlet branch.

(b) Make sure the operating actuator results in a uniform open and close setting of all guide vanes.

(c) Check for impeller blade, inlet guide vane and outlet guide blade for wear/damage.

(d) Check for condition of coupling and renew the rubber bushes if worn out.

(e) Check the joints for wear/leakage.

(f) Use fine strainer while pouring oil.

(g) Do not mix up oil of different quality or lubricant from different supplier.

(h) During annual overhauls make sure that the bearing clearance checked and the bearings are replaced if necessary.

(i) Check up the lubricant condition and make sure that the seals are in order.

(j) Check and lubricate the inlet guide vane bearings.

(k) Clean the deposits from impeller, suction and delivery ducts.

(l) Ensure perfect fan / motor alignment before coupling.

(m) Before releasing the equipment for trial run, after maintenance check up the following:

i) Works have been completed satisfactorily.

ii) Men and material were cleared.

iii) Screws and bolts were tightened properly.

iv) The manhole is closed and insulation is restored if applicable).

v) Interconnecting equipment like regulating gear, monitoring instruments and interlocks are restored back for proper functioning.

SAMPLE QUESTIONS

1. (a) What are possible causes and remedies if the steam pressure is lower than the usual pressure?

   (b) How is the water side of water tube boiler is cleaned for internal inspection.

2. What preventive maintenance should be followed for oil fired automatic package boiler on daily, weekly, monthly and yearly basis.

3. Write short notes Blow Down and Continuous Blow Down of boiler

4. Write short notes Priming and foaming

5. What are the measures to be taken during the operation of a condenser plant?