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Development of an Efficient Maintenance Scheme for Peak Efficiency of Boilers

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Abstract*—Presently the world has enormous advancement in science and technology the topic considered here is just a drop out of an ocean of knowledge. Higher product quality, better reliability, better availability of plants, optimization of cost and efficient working of boilers is the chief concern now a days. Generally the production can be increased by the efficient use of boilers and hence there is a lot of scope to minimize the boiler operation cost. A boiler maintenance improvement program must include two aspects: (1) action to bring the boiler to peak efficiency and (2) action to maintain the efficiency at the maximum level. Good maintenance and efficiency start with having a working knowledge of the components associated with the boiler, keeping records, etc., and end with cleaning heat transfer surfaces, adjusting the air-to-fuel ratio, etc. A well-planned maintenance program avoids unnecessary down time or costly repairs. It also promotes safety and aids boiler code and local inspectors. An inspection schedule listing the procedures should be established. Thus in this paper an attempt is made to develop an efficient maintenance scheme by which boilers can be used with peak efficiency.

***Keywords*— Boiler, Maintenance, Efficiency, Maintenance Activities, Boiler Operation, Safety check list.**

I. INTRODUCTION

A boiler is an enclosed vessel that provides a means for combustion heat to be transferred into water until it becomes heated water or steam. The hot water or steam under pressure is then usable for transferring the heat to a process [1]. Water is a useful and cheap medium for transferring heat to a process [2]. When water is boiled into steam its volume increases about 1,600 times, producing a force that is almost as explosive as gunpowder. This causes the boiler to be extremely dangerous equipment that must be treated with utmost care. Thus it is recommended that boiler room log or record be maintained, recording daily, weekly, monthly, and yearly maintenance activities. This provides a valuable guide and aids in obtaining boiler availability factor to determine shutdown frequency, economies, length of service, etc. Even though the boiler has electrical and mechanical devices that make it automatic or semi-automatic in operation, these devices require systematic and periodic maintenance. Any "automatic" features do not relieve the operator from responsibility, but rather free him from certain repetitive chores, providing him with time to devote to upkeep and maintenance. Good housekeeping helps to maintain a professional boiler room appearance. Only trained and authorized personnel should be permitted to operate, adjust, or repair the boiler and its related equipment. The boiler room should be kept free of all material and equipment not necessary for operation for the boiler. Alertness in recognizing unusual noises, improper gauge readings, leaks, signs of overheating, etc., can make the operator aware of developing malfunction and initiate prompt corrective action that may prevent excessive repairs or unexpected down time. All piping connections to the system and its accessories must be maintained leak-proof because even a minor leak, if neglected, may soon become serious. This applies especially to the water gauge glass, water level control, piping, valve packing, and manway gaskets. If serious leaks occur shut down the boiler immediately and gradually reduce steam pressure. Do not attempt to make repairs while the boiler is under pressure [3].

II. MAINTENANCE ACTIVITIES FOR BOILERS

1. Minimum maintenance activities for boilers

The tables located at the end of this paper indicate items that must be performed to maintain systems and equipment at a minimum level of operational readiness. The listed minimum action items should be supplemented by manufacturer-recommended maintenance activities and procedures for specific pieces of equipment. Maintenance actions included in this section are for various modes of operation, subsystems, or components. Table 1 provides maintenance information for packaged heating boilers. Table 2 provides maintenance information for boiler system instrumentation and electrical systems [4].

2. General maintenance for boilers

This section presents general instructions for maintaining the types of components associated with boilers.

❖ ***Exercise valves***. Exercise all valves in the heating boiler system.
(1) Inspect packing gland and tighten if necessary.
(2) Check for correct positioning and operation.
(3) Check for leaking seals.
(4) Adjust operator linkages and limit switches on control valves.

❖ ***Test alarms***. Verify that the horns sound and all annunciator lights illuminate by pressing the appropriate test push buttons. Press the ACKNOWLEDGE and RESET push buttons when proper operation has been confirmed.

❖ ***Lubricate rotating equipment***. Grease all zerks at the manufacturer-recommended service interval. Grease gently with a handgun to avoid damage to grease seals. Do not over grease.

(1) Ball or roller bearings tend to heat up when over greased and will cool down to normal running temperatures when the excess grease either oozes out or is wiped off. The normal operating temperature of a bearing may be well above 140°F, which is "hot" to touch. Temperatures should be checked with a thermometer and any temperature readings over 180°F should be questioned. If a drop of water placed on a bearing sizzles, the bearing is in distress and should be changed before it seizes and ruins the shaft. For sleeve bearing assemblies with oil reservoirs, service reservoirs at manufacturer-recommended interval with recommended viscosity lubricating oil [5]. Do not overfill reservoir as overheating may result. When new sleeve bearing units are placed in service, drain and flush the oil reservoir after about two weeks of operation and refill the reservoir with new lubricating oil of the proper viscosity.
(2) During equipment overhauls, bearing assemblies should be thoroughly cleaned, inspected, and adjusted in accordance with the manufacturer's recommendations. All old grease should be removed from bearings and the bearings repacked with grease a minimum of every two years. Monitor the operation of all recently installed bearings. Check for overheating (alignment, lubrication), vibration (alignment), loose collars, fasteners, etc. Early problem detection can avoid early failure and costly replacement.

❖ ***Belt drives***. When belt replacement is required replace multiple belts as a set [6]. Loosen drive motor mounting, and slide motor toward driven shaft so that belts may be installed by laying belts onto pulleys. Do not lever belts onto pulleys. Check belt tension several times during first 48 hours that new belts are in operation, and adjust belt tension as required.
(1) When belt tension adjustment is required, consult the belt manufacturer's literature for the proper tension force (and belt deflection to achieve that force). Deflect each belt at the midpoint between the pulleys to the deflection recommended, and read the belt tension. Adjust the tension as required. Many belts have an initial run-in period tension (usually about 48 hours) and then a broken-in tension. Generally, if the tension reading differs more than 2 pounds from the recommended reading, the belt tension should be adjusted. If a belt tension-measuring device is not available, belt tension may be checked by observing the deflection when pressing down on each belt at about the midpoint between the pulleys. If the tension is correct, the belt deflection will be about one belt thickness for each 4 feet of centre-to-centre distance between the pulleys. Caution should be used in using this method because there are many different belt designs available for the same service and each belt design may have different tension and deflection characteristics. To tension the belts, loosen the motor hold-down bolts. Move the motor away from the driven shaft to increase the tension and toward the driven shaft to decrease the tension. (If the motor is on a slide base, it will not be necessary to loosen the motor hold-down bolts. Adjustment is accomplished using the slide base positioning screw.) Tighten the motor hold-down bolts. Run the equipment for a short period of time, and then check the belt tension.
(2) When drive alignment is required, lay a straightedge across both the driver and driven pulleys. The straightedge should contact each pulley in two places. If the pulleys are not aligned, verify that the drive shaft and driven shaft are parallel. If the shafts are not parallel, adjust the motor so the shafts are parallel. When the shafts are parallel, adjust the positions of the pulleys on the shafts to achieve alignment. Verify that the driven pulley is in the correct position on the driven shaft and that the pulley is firmly locked in place. Loosen the pulley on the motor shaft, and move the pulley into alignment with the driven pulley. Tighten the pulley on the shaft, install and tension the drive belts, and run the equipment for a short period of time. Check drive alignment and adjust as required.

❖ ***Packing adjustment***. Occasional packing adjustment may be required to keep leakage to a slight weep; if impossible to reduce leakage by gentle tightening, replace packing. A slight weeping through the packing gland is required so that the process fluid provides lubrication for the packing material. Maintain a supply of the recommended type and size of packing required for the equipment. Do not substitute one type of packing with another without verifying the packing types are compatible. Do not use oversized packing. If diameter of oversized packing is reduced by hammering, early failure of packing may result. A too tight packing joint may interfere with equipment operation, can damage equipment, and, again, may result in early failure of the packing.

The procedure to follow when replacing packing is as follows.
(1) Remove all old packing.
(2) Inspect shaft for wear and replace as required.
(3) Use proper size packing and cut packing into rings using the shaft as a guide. When cutting to length, hold packing tightly around shaft but do not stretch packing. Cut with a butt joint. Do not wind packing around shaft.

(4) Thoroughly clean shaft and housing.
(5) Install one ring at a time. Oil or grease lubrication, if permitted, will assist when packing the ring into the box. Offset joints of each succeeding ring by at least 90 degrees from the previous ring.
(6) If shaft is equipped with a lantern ring, be sure that lantern ring is slightly behind lubrication hole in stuffing box; otherwise, the lantern ring will move forward when the gland is taken up and the packing behind the ring may plug the lubrication hole.
(7) Tighten the gland bolts all the way to seat the packing. Then loosen the nuts until the nuts are finger tight. In most applications, newly installed packing should be allowed to leak freely on start-up. After start-up, tighten packing gland until only 2 to 3 drops a second are leaking. Do not try to stop leakage entirely**.** The leakage lubricates the packing and prevents early failure of the packing and shaft.

❖ ***Mechanical seals***. There are many different mechanical seal designs [7]. As a result, there is no standard procedure for maintaining and installing mechanical seals. Mechanical seal installations commonly fail because the seal was not placed in the correct position. Seal faces may wear rapidly resulting in early seal failure if the spring has too much initial compression. This results in too much force between the faces of the seal, which does not allow proper lubrication of the surfaces. Alternately, if the spring has too little initial compression, the seal faces separate at normal operating pressures and leak. It is important that manufacturer's information for the seals used be obtained and closely followed. In general, there are four critical requirements in any seal installation as follows.
(1) Determine that the equipment is ready to have the seal installed, shaft and seal housing have been inspected and repaired as required, and the components have been thoroughly cleaned.
(2) Place the seal in the correct position for the right operating length (consult manufacturer's data).
(3) Prevent damage to seal rings.
(4) Prevent damage to seal faces.

❖ ***Clean all equipment***. Clean equipment is easier to inspect, lubricate, and adjust. Clean equipment also runs cooler and looks better.

❖ ***Safety relief valve test (steam boilers)***. As precautionary measures, all personnel concerned with conducting a pop or capacity test should be briefed on the location of all shutdown controls in the event of an emergency, and there should be at least two people present. Care should be taken to protect those present from escaping steam [8].
(1) Every 30 days that the boiler is in operation or after any period of inactivity, a try lever test should be performed as follows. With the boiler under a minimum of 5 psi pressure, lift the try lever on the safety valve to the wide open position and allow steam to be discharged for five seconds to 10 seconds. Release the try lever, and allow the spring to snap the disk to the closed position. If the valve simmers, operate the try lever two or three times to allow the disk to seat properly. If the valve continues to simmer, it must be replaced or repaired by an authorized representative of the manufacturer. Inspect the valve for evidence of scale or encrustation within the body. Do not disassemble valve or attempt to adjust the spring setting. It is advisable to have a chain attached to the try lever of the valve to facilitate this test and allow it to be conducted in a safe manner from the floor. The date of this test should be entered into the boiler logbook.
(2) A pop test of a safety valve is conducted to determine that the valve will open under boiler pressure within the allowable tolerances. It should be conducted annually, preferably at the beginning of the heating season if the boiler is used only for space heating purposes. Hydrostatic testing (using water) is not to be considered an acceptable test to check safety valve opening pressure.

A recommended procedure is as follows.

- Establish necessary trial conditions at the particular location. Where necessary, provide adequately supported temporary piping from the valve discharge to a safe location outside the boiler room. In some installations, temporary ventilation may dispose of the steam vapour satisfactorily. Review preparation for test with personnel involved. All such tests should have at least two people present.
- Install temporary calibrated test pressure gauge to check accuracy of boiler gauge.
- Isolate the boiler by shutting the stop valves in the steam supply and condensate return piping.
- Temporarily place jumper leads across the appropriate terminals on the operating control to demonstrate the ability of the high-limit pressure control to function properly. After this has been checked, place another set of jumper leads across the high-limit pressure control terminals to permit continuous operation of the burner.
- The safety valve should pop open at an acceptable pressure, i.e., 15 psi ±2 psi. A simmering action will ordinarily be noticed shortly before the valve pops to the open position.
- If the valve does not open in the 13 psi to 17 psi range, it should be replaced. It is not necessarily a dangerous situation if the valve opens below 13 psi, but it could indicate a weakening of the spring, improper setting of the spring, etc. If the valve does not open at 17 psi, shut off the burner and dissipate the steam to the system by slowly opening the supply valve.
- If the valve pops open at an acceptable pressure, immediately remove the jumper leads from the high-limit pressure control. The burner main flame should cut off as soon as the jumper leads are removed.
- The safety valve will stay open until the pressure drops sufficiently in the boiler to allow it to close, usually 2 psi to 4 psi below the opening pressure. This pressure drop (blowdown) is usually indicated on the safety valve nameplate.

- Relieve the higher pressure steam to the rest of the system by slowly opening the steam supply valve. After the boiler and supply piping pressures have become equalized, open the return valve.
- Remove the jumper leads from the operating control and check to make certain that it functions properly. This is best done by allowing it to cycle the burner on and off at least once.
- Enter the necessary test data into the boiler logbook.

❖ ***Safety relief valve test (water boilers).*** At try lever, test and pop test should be performed for water boilers as described below.

(1) Every 30 days that the boiler is in operation or after any prolonged period of inactivity, a try lever test should be performed as follows.

- Prior to the test, check the safety relief discharge piping to make sure it is installed and supported so this test does not transmit any stress or strain to the body of the safety relief valve.
- Check and log the operating pressure and temperature of the system.
- Shut off circulating pump and fuel burning equipment.
- Isolate the boiler from the system, leaving the expansion tank valve and the automatic fill valve open.
- With the boiler at operating pressure, lift the try lever to the full open position and hold it open for at least five seconds or until clean water is discharged.
- Release the lever and allow the spring to snap to the closed position. If the valve leaks, operate the try lever two or three times to clear the seat of any foreign matter that is preventing proper seating. As safety relief valves are normally piped to the floor or near a floor drain, it may take some time to determine if the valve has shut completely.
- If the safety relief valve continues to leak, it must be replaced before the boiler is returned to operation.
- After it has been determined that the safety relief has shut completely, add water to the boiler until the pressure rises to the initial pressure which was logged at the start of the test.
- Open the valves to the system.
- Start the circulating pump.
- Start the fuel burning system.
- Observe the pressure and temperature until the system returns to operating conditions and operating control has cycled the burner on and off at least once.
- Check again to ensure that the safety relief valve is not leaking.

(2) A pop test (pressure relief valve) should be performed annually, preferably at the beginning of the heating season, if the boiler is shut off during the summer months. The following procedure should be reviewed by the person in charge of the test with at least one other person, and trial conditions should be determined.

- Isolate the boiler from the rest of the heating system by closing the supply and return valves. On large water content boilers, the expansion tank may also be isolated to speed up pressure rise.
- Check the safety relief valve discharge piping to make sure it is installed and supported so that this test does not transmit any detrimental stress to the body of the safety relief valve.
- Temporarily install a calibrated pressure gauge and thermometer to check the accuracy of the boiler pressure gauge and thermometer or remove gauge and thermometer and check calibration and reinstall prior to test.
- Perform a try lever test prior to the beginning of the pop test.
- Check and log the system operating pressure and temperature.
- Shut off circulating pump and fuel burning equipment.
- If an automatic water feeder is provided, close the boiler water inlet valve.
- Turn on the fuel burning equipment.
- Place jumper leads across the appropriate terminals of the operating temperature control and check the operation of the high-temperature cut-out.
- If the high-temperature cut-out functions properly, place jumper leads across the appropriate terminals of the high-temperature cut-out to permit continuous operation of the burner.
- Make sure that all personnel are clear of the safety relief valve discharge**.** On boilers having a small water storage capacity, very little heat will be required to raise the boiler pressure to the popping pressure of the safety relief valve.
- The safety relief valve should open within an acceptable range above or below the set point. This range is ±2 psi for valves set to open at 70 psi or less and ±3 percent of set pressure for valves set to open at more than 70 psi.
- If the safety relief valve does not open at the set pressure plus the allowable tolerance, shut off the fuel burning equipment and do not operate the boiler until the safety relief valve has been replaced.
- Observe the rising pressure and temperature of the boiler, and log the pressure at which the safety relief valve opens. As soon as the safety relief valve opens, turn off fuel burning equipment by removing jumper leads and record safety relief valve closing pressure.
- If the safety relief valve opens at a pressure below the allowable tolerance, this is not necessarily a dangerous condition, but it can indicate a deteriorating condition or improper spring setting.
- The valve should be replaced.
- When the safety relief valve opens, it will discharge a mixture of water and vapour. The valve will remain open until a closing pressure is reached. This pressure may be 20 percent to 50 percent below the set pressure of the valve. There are no blowdown tolerance requirements for safety relief valves.

- After the safety relief valve has closed, add water to the boiler, if necessary, until the boiler pressure rises to the initial system operating pressure that was logged at the start of the test.
- Open the supply and return valves to the system and expansion tank valve, if closed, and open the boiler water inlet valve if an automatic water feeder is provided.
- Start the circulating pump.
- Start the fuel burning equipment.
- Observe the pressure and temperature until the system returns to operating conditions and the operating control has cycled the burner on and off at least once.
- Check again to ensure that the safety relief valve is not leaking.

❖ ***Partial blowdowns.*** It should be made in accordance with the Blowdown Instructions [9]. The Boiler blowdowns must be made sufficiently so that total dissolved solids in the Boiler water between 2600-3200 PPM (3600-4200 micromhos/cm) and mud and sediment are removed from the boiler. The type of blowdown and period between blowdowns can be extended only when the total dissolved solids in the boiler are maintained below between 2600-3200 PPM (3600-4200 micromhos/cm).

❖ ***Proper Grounding*** of the boiler is necessary if there is a possibility of electrolysis (a form of corrosion) and to help maintain normal tube life. Periodic internal inspections are necessary to determine if the thin protective coating has developed in the tubes [10]. Proper grounding of the boiler requires driving a copper rod of 6' or more into the ground. Readings in excess of 35MV on ungrounded installations require grounding to prevent the onset of a corrosion problem.

Safety check list for boilers [11].

1. Test controls and safety devices regularly. Correct any defects immediately.
2. Keep controls and safety devices in proper working condition. For example, blow down the chambers of the low-water fuel supply cut out and operate the lift lever of the relief or safety valve regularly, while the boiler is in service.
3. Have a reliable service organization check and service the equipment periodically, both during and between heating seasons.
4. As soon as possible at the end of each heating season, drain the boiler and clean it both internally and externally. Remove all clean-out plugs. Open and clean the chamber of the low-water fuel supply cut out. Repair furnace brickwork and lay-up the boiler.
5. Examine and repair heating system components and boiler auxiliary equipment.
6. Don't leave broken windows or other openings that may permit wintertime freezing.
7. Don't block the combustion air supply opening for the fuel burning systems.
8. Don't use the boiler furnace as a trash receptacle or incinerator during the idle season.
9. Don't leave the boiler room accessible to unauthorized persons.
10. Don't leave the boiler during the idle season so that the burner can be operated in a routine way by an unqualified operator.

DO'S AND DONT'S FOR BOILER OPERATION [12]

DO'S for Boiler Operation:

- Check and remove any foreign material, tools & tackles, waste cloth and other miscellaneous materials from boiler furnace, drums, headers etc. Ensure all manholes, access doors and openings in the boiler and ducting are securely closed before boiler operation.
- Remove any restriction, obstructing boiler expansion. Remove temporary supports.
- All vents & drains are to be operated as per valve operating instructions.
- Ensure correct functioning of all interlocks and protection of auxiliaries and dampers.
- Position all dampers in air and gas system in start-up position while starting the unit.
- Start-up initial fuel feeding in the boiler should be made only after purging the boiler.
- Check and control the fuel firing rate as per start up curve.
- Check and maintain drum level always near recommended normal operating level.
- Check and control boiler water, feed water and steam conditions as recommended.
- Reduce the load as per the recommended rate. Check and take out the controls on manual only at a point, where good control can be obtained manually.
- Ensure purging of furnace after every fuel trip.
- Note down all minor maintenance works like valve leakage, gland leakages etc. During operation and attend to the same in a planned way during shut down.
- Run the ID and FD fans after boiler shutdown till the flue gas temperature drops down to 100 " C.
- Check periodically for vibration and temperature of bearing, noise level, motor current, etc. for rotary equipment. These values are to be recorded and analysed periodically to ensure planned, preventive maintenance.
- Check for condition of coupling and renew the rubber bushes if worn out.
- Soot blower should be commissioned after initial boiler start-up and should be operated regularly.
- Dump the grate after ensuring that there are no big lumps on the grate section to be dumped.

- Do familiarise with the boiler operating manual and maintain the log book to record boiler operating data and events.

DONT'S for Boiler Operation

- Do not start the fan with inlet damper open
- Do not throw oversized wood pieces on the grate.
- Do not start the boiler without ensuring local drum level measurement / remote indicating instruments are in order.
- Do not start the feed pump with discharge valve open.
- Do not start the boiler when the drum level is below the normal level
- Do not start the boiler without adequate storage of DM / soft water
- Do not feed raw water into the boiler under any circumstances
- Do not operate boiler with known tube leaks.
- Never operate at higher steam temperatures than recommended in the start-up curves as it may harm the super heater.
- Do not mix different type of lubricants from different suppliers. For details of lubrication refer to lubrication chart.
- Do not keep the peep holes or manhole doors open, when boiler is in operation.

Packaged Heating Boiler	
Action	***Frequency***
System	
Check and record pressure and temperature readings.	shift
Perform walk-around inspection of boiler system. Make routine adjustments and repairs when discovered if possible; initiate report orders for items that cannot be corrected at inspection. Tag deficient devices to alert others that item needs repair.	day
Inspection should observe all operating equipment and look, listen, and feel for unusual conditions. Inspection should include:	
Feedwater system (pumps operating, valves open, chemical treatment operating).	day
Safety valves leaking or simmering.	day
Water level controls operating.	day
Filters and strainers are not plugged.	day
Devices such as steam traps, drain cooling valves, etc., are operating properly.	day
For fuel oil fired systems, level of fuel oil is adequate and fuel feed equipment is operating properly.	day
Safety and Ignition Devices	
Inspect, operate, and report on all safety and ignition devices. Report all deficiencies found. Where possible, make required adjustments or repairs to device during inspection. Otherwise, tag device to alert others to deficiency and initiate repair order. Devices to be inspected and tested include:	
All systems:	
Pressure relief valves.	mo
All low water shutoff devices.	mo
All flame detecting devices and operation of flame supervisory control system.	mo
Ignition transformer.	mo
Modulating motor transformer.	mo
Combustion air proving switch.	mo
Combustion air control damper.	mo
Steam Boilers:	
Operating limit pressure control.	mo
High limit pressure control.	mo

Table 1

Packaged Heating Boiler	
Action	*Frequency*
Modulating pressure control.	mo
Hot Water Boilers:	
Operating limit temperature control.	mo
High limit temperature control.	mo
Modulating temperature control.	mo
Gas Fired Boilers:	
Gas pilot solenoid valve.	mo
Gas pilot solenoid vent valve.	mo
Gas pilot pressure regulating valve.	mo
Main gas pressure regulating valve (if required).	mo
Main gas modulating cam.	mo
Main gas solenoid valve.	mo
High gas pressure shutdown switches.	mo
Main gas solenoid vent valve.	mo
Low gas pressure shutdown switches.	mo
All Oil Fired Boilers:	
Oil drawer switch.	mo
Atomizing air proving switch.	mo
Low oil pressure shutdown switches.	mo
Main oil solenoid valve.	mo
Fuel oil controller.	mo
Heavy Oil Fired Boilers:	
Startup electric oil heater thermostat.	mo
Main oil heater thermostat.	mo
Low oil temperature switch.	mo
High oil temperature switch.	mo

Table 2

Packaged Heating Boiler	
Action	***Frequency***
Fan, Pump and Other Rotating Equipment	
Observe operation and check for unusual noises, vibration, and overheating. Investigate and report all unusual conditions. When possible, make adjustments and repairs when condition is observed. When immediate correction cannot be accomplished, initiate work order and tag equipment to alert others of condition.	day
Lubricate equipment:	
Sleeve bearings.	mo
Ball bearings.	3 mos
Roller bearings.	mo
For belt driven equipment, check condition of drive belts and pulleys, and belt tension. Replace components, and adjust belt tension as required.	mo
Thoroughly inspect equipment (partial disassembly may be required) and service equipment in accordance with manufacturer's recommendations.	yr
Strainers and Filters	
Check pressure drop across strainer and filter elements. Clean or replace element if pressure drop exceeds design value.	week
Clean all filters and strainers.	3 mos
Steam Traps	
Check temperature on both sides of steam trap. If above the boiling point several feet past the steam trap, it has failed in the open position.	3 mos
Burner Assembly	
Visually check flame during operation. Investigate unusual conditions and make adjustments to burner, combustion air, and fuel train to achieve optimum air-fuel ratios. Perform value gas analysis as required.	week
Perform flue gas analysis and adjust burner as required.	3 mos
Clean and inspect burner assembly and combustion control equipment. Adjust or repair as required.	6 mos
Rebuild burner assembly in accordance with manufacturer's recommendations.	yr
Fireside	
Inspect combustion chamber and flue gas side of boiler equipment. Report all deficiencies. Make all possible adjustments and repairs during inspection. For items that cannot be corrected during the inspection, initiate work orders to correct the conditions. Inspection and routine maintenance to be performed during the inspection shall include:	

Table 3

Packaged Heating Boiler	
Action	*Frequency*
Vacuum, brush, or scrape all soot and obstructions from combustion chamber walls, fire tube walls, and exhaust gas flues.	6 mos
Inspect refractory liner for deterioration.	6 mos
Inspect metal surfaces for corrosion, cracking, or other deterioration.	6 mos
Waterside	
For steam boilers with minimal makeup water requirements (no condensate or makeup water treatment program – usually small boilers operating at 15 psig or less), drain and flush boiler, and refill boiler with chemically treated, softened, or deionized water.	6 mos
For closed loop hot water boilers, drain and flush boiler, and refill boiler with chemically treated, softened, or deionized water.	yr
For steam boilers with water treatment systems:	
Verify operation of makeup water and feedwater treatment equipment and systems. Includes checking levels in chemical supply tanks and preparing additional chemical treatment solutions as required.	day
Test water and adjust chemical treatment as required.	week

Table 4

Boiler System Instrumentation & Electrical	
Action	*Frequency*
Level Gauges	
Check for accuracy. Recalibrate as required following equipment manufacturer's instructions.	yr
Thermometers	
Check for accuracy. Remove thermometers from their wells and check against calibrated thermometer in controller temperature bath.	yr
Pressure Gauges	
Isolate pressure gauge by closing the proper valves. Remove and check in a fixture against a calibrated gauge. Adjust as required following equipment manufacturer's instructions.	yr
pH Probes	
Remove probe from line and rinse with fresh water. Calibrate pH unit in accordance with manufacturer's recommendations.	week
Conductivity Probes	
Remove probe from lien and rinse with fresh water. Calibrate conductivity unit in accordance with manufacturer's recommendations.	week
Motors	
Check and clean cooling airflow passages on electric motors as necessary so that nothing obstructs airflow.	6 mos
All Electrical	
Check, clean, and tighten terminals at motors, starters, disconnect switches, etc.	6 mos
Wiring	
Check insulation on conductors in starters, switches, and junction boxes at motors for cracks, cuts, or abrasions. Replace wiring as required and correct cause of damage.	6 mos

Table 5

III. CONCLUSIONS

The importance of boiler maintenance goes beyond reliability. Conducting regular maintenance also reduces boiler operating and energy costs, improves safety, and extends the life of the boiler.

Daily maintenance:

- Check the floor under and around the boiler for leaking water.
- Ensure the boiler area is unobstructed and free of any combustible materials.
- Check pressure and/or temperature readings to ensure they are within the designed range.
- Look for any service codes or errors on the display panel (if applicable). Write down any error codes and provide them to your service contractor.
- Ensure the vent termination is not blocked with snow, ice, or debris.
- Check to ensure the combustion air opening is unobstructed.
- Check for any unusual noises or vibrations

Monthly maintenance:

- Visually check the flue gas vent piping and combustion air piping for any signs of blockage, leakage or deterioration.
- Inspect the boiler relief valve and the relief valve discharge pipe for signs of weeping or leakage.
- Check the condensate drain system (drain line, PVC fittings and drain trap) for blockages (condensing boilers).

Periodic maintenance (as required):

- Visually inspect boiler hydronic piping for leaks.
- Inspect burner flame (if possible). If flame appearance changes from the norm then corrective action should be taken.
- Have low water cut off tested to ensure device is working properly.
- Low water cut off is a device used to ensure water levels within the boiler do not drop below manufacturers recommended levels.

Annual service technician maintenance at start-up or when necessary:

- The annual servicing should be performed by a qualified installer or service agency trained and licenced to do maintenance on your boiler.
- Thoroughly inspect heating system and address any problems.
- Inspect and clean the boiler heat exchanger.
- Check all boiler wiring and connections.
- Check water PH levels.
- Inspect condensate system and clean and flush as necessary.
- Inspect and clean burner assembly (including ignitor and flame sensor).
- Inspect venting system for blockage, corrosion or deterioration and ensure all joint and pipe connections are tight.
- Inspect air inlet and vent terminations to ensure they are clear and unobstructed.
- Check control settings and test operating and safety controls.
- Check for proper boiler operation after it has been cleaned and inspected.

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