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A Review on Recent Techniques for Boiler Tubes Corrosion Protection and Fouling Mitigation Using PLC

Raheek I. Ibrahim*, Manal K. Odah, Hind A. Sami

***Electromechanical Engineering Department, University of Technology, Baghdad*- Iraq**

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ABSTRACT

Abstract- *A steam boiler is a metal vessel in which a particular liquid is heated to steam. Steam is used in the production of energy in several areas as most boilers convert water to steam used in heating buildings and others. Steam boilers are exposed to corrosion and sediment as a result of salts dissolved in water, which may lead to increased temperature inside the boiler and thus the boiler explosion. The research included finding a suitable way to solve the problem of sediment and corrosion by adding suitable chemicals to get rid of the dissolved salts inside the water and maintain steam boiler. To control this problem, the control system is designed to control the amount of salts in the water in the steam boiler using PLC.*

1. Introduction

The boiler is a combination of devices to produce heat, retrieve and utilize them and transfer them to the feed water to be heated and evaporated and converted to steam. Its use can be classified for heating purposes and generating mechanical energy used in generating electric power and others. In addition to there are many cases of water, including solid, liquid or steam, water vapor is a state of water evaporation, which contains thermal energy enters in many industrial processes ranging from heating the air to evaporation of liquids in refining processes.

Industrial plants need water vapour significantly as it can enter the field of power generation and is also used for heating purposes at the lowest possible pressure and according to the requirements of heating temperature [1].

2. Steam Formation Process

As is known when applying heat to water, it causes a high temperature. The water does not reach 212 ° F in the case of the water heater, so it is not boiling, but it could be if the temperature sensor did not work properly and the safety valve above the tank was blocked. The temperature would rise past boiling (saturation), and then the additional heat added would turn the water into steam. When the water is converted to steam it contains a percentage of salts [2], the following diagram shows the stages of turning water into steam:

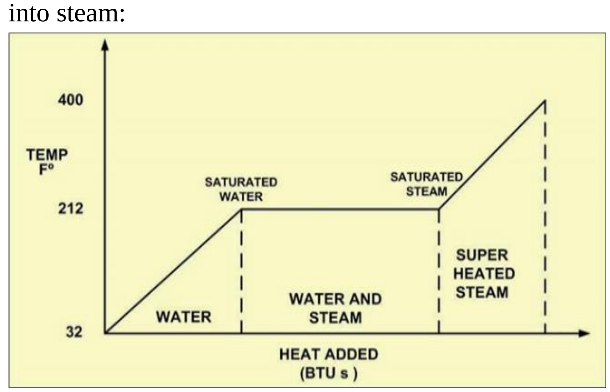
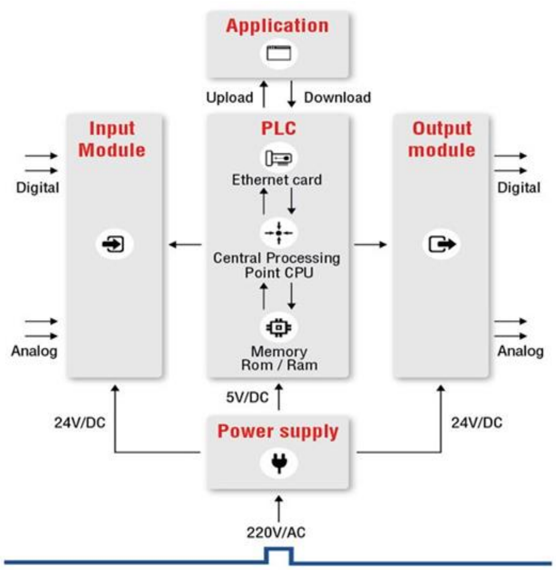


Figure 2: Flow diagram of water to steam [3]

*Corresponding author: : Raheek I. Ibrahim ; doctorraheek@yahoo.com ; +9647834227611

2. **Programmable Logic Controller (PLC):**

A programmable logic controller, commonly known as PLC (Programmable Logic Controller), it is a specialized tool commonly used for automation in different industries. It is used rather than automating a car manufacturer that uses robotic arms, locations where motors must be powered when a control signal is provided, electrical power system for the operation of circuit breakers, etc. PLCs are programmable, making it a flexible system that can be used as a single unit depending on where it is used for different types of operations. Big advantage of a PLC over the stable design of traditional controllers. In most dynamic environments, it has high fidelity. PLC is peripheral noise tolerant and is therefore a robust control system where precision and reliability prevail. The important advantage of a PLC is its ability to handle several ports for both analog and digital input and output



[4].

Figure 3: Input and output of the PLC [5]

4. Boiler water contaminants:

Many of the localized corrosion and embrittlement mechanisms discussed below are active in steam systems as moisture is transferred or contamination is volatilized during the steam cycle (i.e. silica and high pressure copper). Some of the failure mechanisms found in steam path equipment include overheating from sediment build-up or steam flow blockage, under substrate corrosion (usually from caustic salt carryover), pitting, corrosion fatigue cracking, and embrittlement (mainly caustic SCC). Maintaining steam purity is important to prevent forced outages of steam system components associated with catastrophic fracture or localized corrosion. Due to water chemistry upsets causing foaming, damaged or incomplete steam separation equipment or excessively high concentrations of steam drum water and/or water contamination used for steam processing, moisture transfer to the steam cycle will eventually accumulate aggressive species in super heaters, reheating tubing, steam and turbine equipment. Even due to SCC (Stress Corrosion Cracking) or other localized damage to corrosion, downstream components such as steam expansion joints, condensers and feed water heaters exposed to polluted steam can fail. Stainless steel expansion joints are especially susceptible to caustic SCC in steam systems. 10Failures may occur quickly, sometimes within 24 hours of the initial incident of contamination. In addition, ammonia entry into the steam phase can significantly harm condensers in copper alloy and feed water heaters. The SCC is also of primary concern in this case. The brass tubes used in these systems can crack in ammonia species [6].

4.1 Energy Loss due to Improper De-aeration of Boiler Feed water:

Since maquillage water contains significant amounts of dissolved oxygen, corrosion becomes a critical concern for reliability because the oxidation process is accelerated by high heat intensity at the boiler tubes. Therefore, oxygen-free feed water must be made to the boiler. Steam with as little as 1% by volume of air can also reduce heat transfer efficiency by up to 50%. Therefore, focus is of significant importance to the de-aeration process as well as to the proper functioning of air vents. Deaerator is the device most widely used to extract dissolved oxygen. Just briefly, the de-aeration process uses live steam to take the feed water to around 105 ° C and mechanical agitation to force off the water's oxygen. The released dissolved oxygen must be continually removed from the deaerator and therefore an agreed industrial standard is a small amount of purge vapor from the deaerator [7].

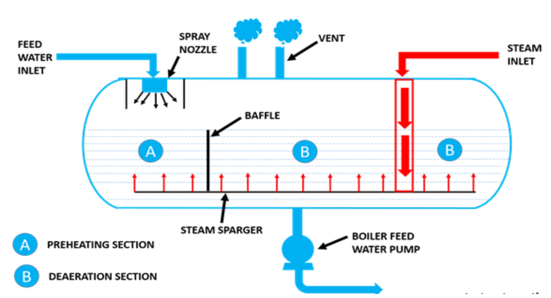


Figure 4: De-aeration process [3]

4.2 Boiler Water pH Control:

The pH of the water in the C (Condensate), FW (Feed Water), B (Boiler) process is regulated downstream of the CEP (Condensate Extraction Pumps) discharge by chemical additions. In this region, online pH (Potential of Hydrogen) measurements are performed before the feed heaters of the LP (Low Presure). Thus the water pH of the boiler is controlled by keeping the feed water at the right pH. Although the value of the desired C, FW, B system operating pH depends on the materials used in the vessels and piping, it is always alkaline. In the existing CANDU stations, e.g. BNGS-B (Burlington Nuclear Generating Station) and DNGS-A (Darlington Nuclear Generating Station), the condenser and feed-heat tubes are made of stainless steel and the valves and most other parts are made of carbon steel. So the process C, FW, B is basically "all ferrous." Copper alloy tubing is used in condensers and feed heaters in older stations, e.g. PNGS (Pickering Nuclear Generating Station) and BNGS-A, while carbon steel tubing and parts are used elsewhere in the system C, FW, and B. This mix of materials creates a problem of chemical control in that the optimum pH for copper alloys is 6-9, while it is 10-12 for carbon steel. Thus the copper / ferrous system chemical control differs from that of all-ferrous systems [8].

4.3 Total Dissolved Solids (TDS):

All inorganic and organic substances found in water can pass through a 2 micron filter are the total dissolved solids (TDS). TDS-composed ions and ionic chemicals typically include carbonate, bicarbonate, chloride, fluoride, sulphate, phosphate, nitrate, calcium, magnesium, sodium and potassium, but any ion present can contribute to the total. Pollutants, herbicides and hydrocarbons are among the organic ions. Soil organic products such as humic / fulvic acids are also included in TDS. There are a number of ways in which TDS can be measured. The easiest way to treat the water sample is to evaporate it at 180 ° C in a pre-weighted dish until the weight of the dish is no longer variable. The TDS reflects the weight change of the platter and is recorded in mg / L. A water sample's TDS can also be measured fairly accurately using a linear equation of correlation depending on the sample's electrical conductivity. At last, by weighing individual ions and simply adding them together, TDS can be measured [9].

5. Boiler Tube Failure Mechanism:

Corrosion under deposits often leads to pipe failure before sufficient deposit is accumulated to overheat failure. Porous iron oxide deposits typically facilitate corrosion. If localized boiling occurs, caustic gouging can be observed under the porous sludge layer on the boiler drain. The process is easy, the water under the sludge becomes steam, and boiler water is drawn in to extract it. The water contains salts, including caustic salts, continues to boil, and caustic content is very high. Caustic concentrations under the sludge of 100,000ppm are not uncommon. High rates of caustic dissolve on the surface of the boiler tube the protective metal oxide layer. The oxide changes, then dissolves again afterwards. The impact is a distinctive pattern of gouged metal removal, resulting in failure. Figure (6) shows the caustic gouging process.

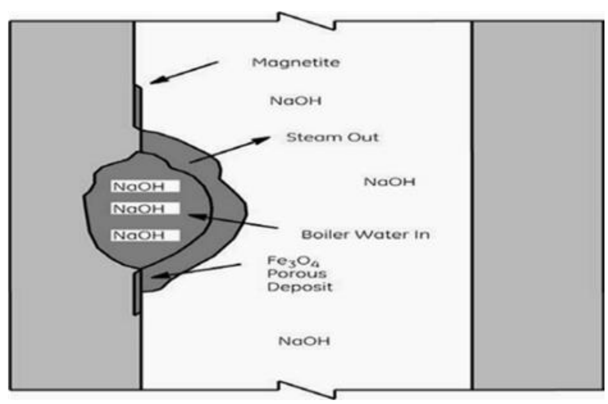


Figure 6: Porous deposits have conditions supporting high levels of strong boiler gas, such as sodium hydroxide (NaOH) [6].

6. Scale build-up:

Scaling is a coating that is formed inside the piping and heat transfer surfaces when the water is heated and impurities precipitate or settle, leaving extremely hard deposits.

Many common water contaminants causing scaling include:

- Iron
- Aluminium
- Silica
- Calcium
- Magnesium

The degree of scaling on a boiler is determined by the amount of these impurities, in comparison to the pressure exerted by a boiler. To example, some boilers with higher pressure would require higher water quality and lower pollutants than some boilers with lower pressure. For example, boilers that generate steam to power turbines need high-pressure boilers and hence a more complex feed water treatment system to remove as many impurities as possible [10].

Figure (7): Scaling phenomenon [11]

7. Corrosion:

Corrosion is the deterioration of material properties due to contact with their environment, and corrosion is unavoidable for most metals (and most materials for that matter). While all material forms are primarily associated with metallic materials, they are prone to degradation. A problem in aging aircraft was the corrosion of polymeric insulating coatings on wiring. By selective dissolution, even ceramics can be degraded. Corrosion is something we hope to avoid, like death and taxes; but in the end, we need to learn to deal with it. Reducing the frequency of a system's Gibbs is the main cause or driving force for all corrosion. As a result of this uphill thermodynamic battle, the metal has a powerful driving force to return to its natural, low-energy oxide state. A return to the native oxide state is what we call corrosion, and while it is unavoidable, it is possible to use significant barriers (corrosion control methods) to delay their progress toward equilibrium. Therefore, the rate of equilibrium approach is often of concern. This frequency is dictated not only by the existence of the metal surface, but also by the composition of the atmosphere and the creation of both [12].

Type of corrosion cells:

١) Galvanic cells
٢) Concentration cells
٣) Electrolytic cells
٤) Differential cells of temperature [13].

8. Chemical Conditioning to Minimize Corrosion:

It is possible to apply chemical conditioning to both feed water and boiler water. To regulate the above-mentioned corrosion processes, guidance limits must be established. The first precondition is to reuse the condenser's high purity feed water or to use it as a makeup. Purity is regulated after condensation by conductivity measurement, feed water, boiler and evaporator water, and steam cation exchange [14].

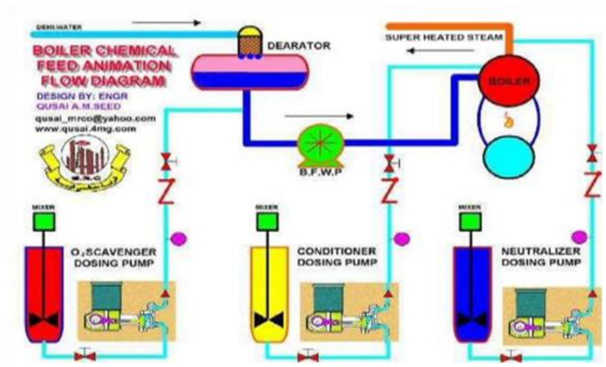


Figure 8: Scheme of injection of chemicals into the boiler [2]

Such studies involve corrosive contaminants including chlorine, sulfate, carbon dioxide, and organic anions. The higher the ambient temperature and pressure, the higher the purity of water needed to prevent corrosion, and therefore the lower allowed by CACE (Conductivity after cation exchanger). To raise the pH, a volatile alkalizing agent, usually ammonia, is added to the feed water. In some specific cases, an organic amine may be added.

There are three variants that can be applied to the feed water:

- Reducing all-volatile (AVT(R)
- Oxidizing all-volatile (AVT(O)) treatment
- Oxygenated (OT) treatment [14].

9. Techniques for feed water treatment:

In order to ensure an efficient process and quality steam output, some form of boiler feed water treatment system is usually required for industrial companies that use a boiler for their factory. The most suitable boiler feed water treatment system will help the facility avoid expensive plant downtime, expensive maintenance fees and boiler failure due to boiler and downstream machinery scaling, oxidation and fouling. A boiler feed water treatment system is a multi-technology device that meets the water treatment needs of your specific boiler. Both high- and low-pressure boilers, boiler feed water must be treated. Ensuring proper treatment before issues like fouling, scaling and oxidation will go a long way to avoid costly replacements / upgrades down the line [15].

It should be possible to have an effective and well-designed boiler water treatment system:

• Before entering the boiler, treat boiler water efficiently and remove harmful impurities
• Promote control of internal boiler chemistry
• Maximize the use of condensate from steam
• Command of corrosion on the return line
• Avoid downtime and malfunction of the boiler
• Extend the service life of the equipment [10].

N. Hare, M.G. Rasul an S. Moazzem (2010) Recommended for many sedimentation mitigation strategies Boiler issues such as wave pulse blasting technology, smart fire blower, anti-fouling paint, chemical processing technology, etc. In order to avoid spotting problems, the effectiveness of these techniques is addressed. Conclusion of observations and recommendations are made according to their effectiveness [16]. **Rahul Dev Gupta et al. (2011)** The results of the boiler house efficiency improvement study conducted in the pulp and paper mill's large boiler house system were discussed. Different heat losses such as loss due to unburnt coal in refuse, loss due to dry flue gas, loss due to fuel humidity, loss due to radiation, loss due to blow down, and loss due to burning hydrogen, etc., were the causes of poor boiler performance. The different heat losses have been evaluated and a collection of recommendations have been made for implementation to the plant management to improve boiler performance [17]. **P. K. Bhowmik S.K. Dhar (2012)** explained the operation and control features of the steam boiler gas burner management system and discuss the smooth operation system, structure and implementation using programmable logic controller (PLC). The PLC system takes into account all requirements for the safe start, safety and operation of the burner. This study may help professionals gain a clear understanding of PLC-based burner management system design, development and analysis for steam boiler [18]. **Amit Kumar Jain (2012)** Optimum preventive maintenance strategy for effective boiler operation was introduced. From an effective preventive maintenance approach, Boiler can operate efficiently. For those plants which depend on maintenance breakdown or failure, it would be particularly beneficial. There are many advantages to having an efficient maintenance plan. The incentives include all forms and sizes of crops. The rule on preventive maintenance strategy is that the higher the value of plant assets and facilities per square foot of the facility, the higher the return on a preventive maintenance strategy [19]. **A. Ashokkumar (2012)** recommended that thermal power plant boilers operate efficiently to achieve maximum output in today's plant market economy. Many of today's boilers are operating less than 60 percent effectively. Thus there is tremendous potential to improve energy and save costs leading to higher Profits. To achieve this goal, the performance of boilers is evaluated and based on it Correction measures for inclusion. Due to the sharp rise in fuel prices and other resources, it is absolutely essential to make maximum use of resources. This can be achieved by calculating the heat losses in boilers and then finding suitable ways to reduce losses, and this paper handles the same [20]. **Sunudas T, M G Prince (2013)** study was carried out at Surat site in steam boilers in the textile industry. Thanks to an erroneous knockdown, 1.5% of coal is lost from overall coal consumption in the industry. By improving boiler blasting and optimizing heat waste recovery by blasting, this work aims to prevent waste in coal use [21]. **Mohammed Imran (2014)** explain the corrosion material transported into the boiler in the feed water system and is collected on the water wall tubes ' inner layer. Proper boiler feed water treatment effectively prevents feed water heaters, economizers, and de-aerators from corrosion. This refers to overheating and onloading corrosion and finally pipe failure. Heat is passed on a metal surface through a thin layer of overheated water, the temperature gradient rises to about 10oC as the heat transfer rate increases and the fluid boiling point approaches the failure of boiler tubes due to corrosion attacks was common in power plants resulting in the plant being shut down unplanned [22]. **Chayalakshmi C. L et al. (2014)** She noted that the accumulation of soot and scale in boilers remains a major concern to improve the boiler's output. Now, once per shift soot fans are powered manually. Now, once per shift soot fans are powered manually. This paper describes one of the embedded industrial automation technologies implemented in the successful activity of Soot informers. Using the ARM7 platform, automation software is developed and implemented in real time. The temperature of the stack is used as the soot blower control standards. Embedded in the language C used to implement automatic control algorithms. The developer's performance is checked in the laboratory [23]. **Dr. Gary B. and Pamela S. Williams Honors (2016)** recommend the use of the Programmable Logic Controller (PLC) to control the water pump in order to maintain the water level in the tank at the desired rate. A proximity sensor is mounted above the upper reservoir to measure the distance from the sensor to the level of water that will be returned to an Allen-Bradley Compact Logix Consider using a Programmable Logic Controller (PLC) to monitor the water pump to maintain the level of water in the tank at the desired time. To control the water level, an AC speed control drive that can receive instructions from the PLC is connected to a water pump that scales back the RPM as the water level falls below the set point and reduces the rpm as the water level exceeds the set point [24]. **Raheek I. Ibrahim et al. (2018)** Specified that the water blast is most of the water purposely removed during the boiler cycle to reduce the level of impurities in boiler water to an acceptable level. So it's got a lot of thermal energy. The goal of the current work is to increase the South Refineries Company / Basra's energy efficiency of steam boilers. This goal was accomplished by designing and manufacturing heat exchangers consisting of a shield and coiled tube structure to extract heat from the water surface of Detonate and to minimize indirect losses. The heat exchanger in Atmospheric pressure passes through the side of the shell and the feed water (cold liquid) on the side of the coil tube is fed with down light (hot liquid) steam. This was the flow monitor as well. The flow control valve is used under the heat exchanger to control the flow rate of hot water. Experiments are performed at water leakage and water flow rates ranging from (0.06-0.14) m3/h at 0.02 m3/h intervals and from (0.1-0.5) m3/h at 0.1 m3/h intervals, respectively. Proven test results the heat recovery system performance to improve the boiler production is 83.16 percent of the energy is lost due to precipitation that can be recovered using a 103411.8 MJ / day energy savings heat recovery unit. This will provide a volume of 482.46 tons of fuel per year. The heat recovery system has been shown to be a good solution to save energy and reduce harmful emissions to the environment and help protect sewage pipes from damage caused by heat discharge water by cooling water before discharge into the sewer system. [25]. **D. Jeevanandan & Jose ananth vino (2019)** project aims to restore the boiler by designing a heat exchanger, which lowers the water temperature. The liquid detonation temperature in the flash tank is roughly 110 0C. You can use this heat to heat the boiler. Heat exchange system by heat recovery to the detriment of which fuel consumption can be reduced. The heat assessed in the falling liquid is transferred to the treated make-up heat by installing the Heat Exchanger Recovery System. Then the heated maquillage water is guided through the adapter. The main reason for this heating process is the reduction of gas, which is the main heating source [26].

10. Conclusions:

In steam boiler corrosion has various kinds and styles. It can be controlled by controlling technological methods such as (chemical additives that affect pH lifting), correct tests, proper operation, and improving all conditions responsible for factors that help control corrosion rate in boilers. As a result, the energy efficiency of the plant has been improved and the safety of workers in this system has been preserved, as well as the maintenance of the system in accordance with environmental conditions.

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