Optimization of an Industrial Boiler Operation

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Abstract— A boiler is a device that converts chemical energy to heat energy. Boilers are widely used devices for industrial purposes to generate hot water and steam. A boiler system with higher efficiency is essential for system performance. The boiler water treatment process is crucial and increases boiler efficiency operations. This paper discusses how to treat water, reduce cost by using alternative fuel. Another essential thing is heat recovery and energy management. In the water treatment part, discuss what the problems are and what the solution is. In cost reduction, part discusses what the alternate fuel is and how it works. Also, discuss how can heat recovery methods and how to manage energy. This paper discusses how to optimize, improve, and apply the above operations for industrial boilers.

Keywords: Boiler water; Ion exchange; Reverse osmosis; heat recovery; energy management

1 INTRODUCTION

In Sri Lanka, There are so many Industry thousands of Industry Use Steam Boilers. Industrial Hot Water generation and steam boilers play the leading role in supplying energy hot water, high-pressure steam for the industrial process. A steam boiler or hot water generates efficiency can increase the good maintaining of feed water. Most industries water consumed for various purposes boiler also needs feed water that feed-water has the same quality. Those are non-corrosive and non-scale forming. These two is the main thing. If feed water help to corrosion water tube may leak, and the boiler may blast. If feed water helps to scale, forming efficiency goes down because of poor heat exchange.

FEED WATER TREATMENT FOR BOILER EFFICIENCY

Feed-water should maintain good quality and some standard. It will help avoid boiler tube damage and increase efficiency; every industry uses surface water or groundwater as feed water for the boiler, but feed-water should have maintained quality. Mainly should remove dissolved solids, suspended solids, and organic material. These can summarize below with small details [1].

- **Iron** - natural water contains soluble iron. it can deposit on boiler parts and tubes, it many damages. Downstream equipment and reduce the quality of some manufacturing process
- **Copper -** cause of deposits to settle in high pressure boilers, decreasing their efficiency and require costly cleaning chemical and equipment
- **Silica** - cause of silica forming hard scaling in low levels.
- **Calcium -** In Sri Lanka most of area surface water or ground water.it contain calcium. calcium scaling in several for depending other chemical.
- **Magnesium -** In Sri Lankan water content highest amount of magnesium. it attracting more solids and contributing to scale.
- **Aluminum -** deposits as a scale and react with silica to increase scaling.
- **Hardness** - hardness also causes deposit and scale on boiler tube and equipment.
- **Dissolved gases** - mostly oxygen and carbon dioxide dissolved in water these two gases can cause severe corrosion on boiler tubes and other parts.

There are four types of water streams in the boiler operation.

- **Make up water -** the raw water, softened water, or demineralized water to generate steam.
- **Condensate water -** steam transfers its heat to the process, it comes to the liquid phase called as condensate. Condensate water no need to treatment because condensate water is very pure.
- **Blowdown water** - The purposely drained water to limit the level of impurities to an acceptable level.
- **Feed water -** the combination of makeup water, condensate water which can fed to the boiler to make inlet water stream.

To achieve a successful water treatment approach requires

- Maximize the condensate quantity
- Improve internal boiler safety
- Maintain boiler tubes and pipes
- external water treatment unit
- Monitoring and control standard quality of feed water

Before mention the water quality but here with some parameters can be summarized below.

pH - normal pH rang is 0 to 14. It is indicate with H^+ ion s in solvent or medium. In water treatment consider about water. pH value control is very important to avoid the corrosion. low pH value helps to accelerator to corrosion. according to the ASME guideline, the boiler water pH level should be maintained above 9.5 it helps to proper maintain boiler unit.

conductivity -In room temperature water's ability to conduct electricity, conductivity depends on how much minerals dissolve in water.

Alkalinity-This is about bicarbonate, carbonate, and hydroxyl irons in water. Alkalinity and pH are interrelated problems in boiler water treatment. If the pH value increases, alkalinity also goes high when boiler heating will break bonds and make carbonic acid. Carbonic acid causes calcium carbonates. Magnesium carbonate will create a scale. That's why we should control alkalinity.

Hardness - hardness about calcium and magnesium ions. Hardness cause to scale formation Hardness control using softener.

Water related issues

There are two types of issues run in water with boiler operation, scale formation and corrosion impact. The most common problem is scale formation not only boiler operation. it causes day today water boiling also main impurities are calcium magnesium and silica when the high temperature operations. The dense coating of material inside the water tube and boiler shell. This coating as called "scale" this scale acting as insulating layer for the heat transfer mechanism. high impact scale cause of silica. It cannot be removed any chemical treatment.

- Scale acting as insulating layer. It is avoiding the heat transfer and heat exchange rate goes down boiler efficiency also goes down
- Sometimes cause of scale minimize the water flowrate

Due to the scale formation fuel consumption increase by 2% for water tube boilers and 5% for five tube boilers approximately [1].

Methods of controlling scales

There are two type of a water treatment such as external treatment and internal treatment. Four type of Externally treatment available those are de alkalization, de mineralization, softener and reverse osmosis. Industrial purpose use softener and reverse osmosis [2].

Water softener

In this process can remove the hardness of the water by iron exchanging process. The softening media technically called as polystyrene resin. Generally called as zeolite. it can attract positive chargers of highly metallic irons. a softener tank contains thousands of zeolite beds. these beds have negative irons. They attract positive irons. If the hardness value less than 5ppm it can consider as soft water. Time to time should recharge the softener with sodium irons, a softener is back flushed with salt brine solution during a backflush. the brine solution replaces the calcium and magnesium irons on the exchange medium with sodium irons from the salt solution [2]. The time between recharging cycles depend on the hardness of the water. The amount of water used the size of the unit and the capacity of the exchange media to remove hardness. Fig.1 shows general method of removing hardness of water [2].

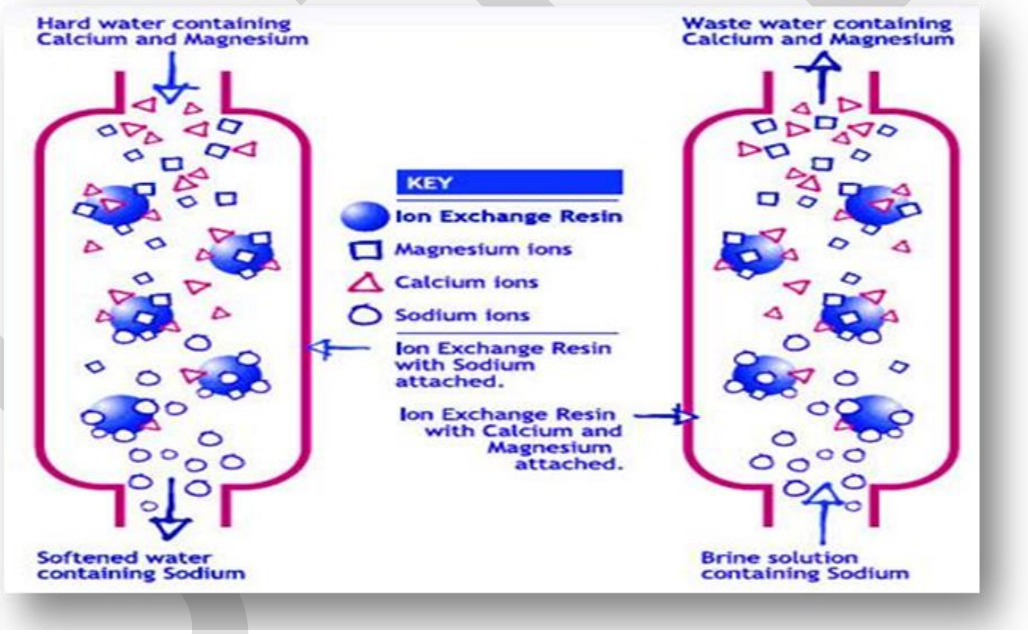

Fig 1. water softener

Reverse osmosis

Reverse osmosis (RO) is best way to remove certain unwanted contaminants from boiler feed water. Reverse osmosis treatment of boiler feed water can reduce all contaminants such as lead or nitrates [3]. The RO unit basic part is the semi-permeable membrane, made within cellulose acetate or thin film composite material. The membrane is placed between two screens and wrapped around a tube. Normal industrial water pressure forces water through the membrane. Occasionally, a pump must be added to increase industrial water pressure and enhance membrane efficiency. The membrane removes dissolved substances in the water and allows only well

cleaned water to pass through. Purified water then sends to a storage tanks and the waste water goes to drains [3].

Advantage and disadvantage

- In advantage of reverse osmosis can remove many dissolved substances efficiently.
- RO plants do not add any other chemical therefore is cause to prevent side effect to boiler lifetime.
- Reverse osmosis system is very expensive.
- A water softener can be to keep the membrane working at its best. But RO membranes are should maintain and its water quality is low .
- Reverse osmosis units cannot remove harmful microorganisms.
- A well-maintained reverse osmosis system can provide feed water with good quality water for all purposes, as long as industry recognize its limitations.

USAGE OF ALTERNATIVE FUEL IN BOILER FOR COST REDUCTION

Boilers are used to produce steam. burning a fuel in the furnace generate heat and turns to water into steam. Nowadays, The Coal is preferred as the most suitable fuel for the boiler. These boilers can reach up to efficiency of about 90% [4]. The Coal has a good amount of Calorific Value than diesel. but overall cost reduction is the one of the important objectives of every industry. It is found that during every financial year the amount spends on purchasing coal goes on increasing. the usage of some alternative fuels in place of coal fuel very important for reducing the overall production cost [5].

Type of alternative fuel

- Straw and Husk
- coconut shell
- cashew shell
- Coconut Husk
- Industrial West (Sugar Industry -Bagas)
- Wood
- Wood powder

Straw and Husk

The cultivation of rice results in two major types of biomass wastes – Straw and Husk –having attractive potential in terms of biomass energy. Although this technology for rice husk utilization is done in industrialized countries of Europe, such technologies are yet to be introduced in the developing countries.Fig.2 shows rice husk. It remove as waste from rice.

Ton of Rice paddy produces 220 kg Rice Husk [5, 6]. Rice husk used for power generation through the steam or gasification way. For small power plants, the gasification method has attracted more attention as a small steam generating plants are very inefficient and it is very difficult to maintain In addition, for rice mills runs with diesel engines,

Fig.2 Rice Husk

These product can be used in the existing engine in a dual fuel operation.

In Sri Lanka, alternative fuels like cashew shell, coconut shell, rice husk are easily available. most Sugar Factory, the waste product bagasse was used to supply heat to the boilers. As bagasse is a waste product, it can be used in a good way. Even bagasse has a good calorific value [6].
alternative fuel boilers and solid fuel fired boilers are environmentally friendly energy options and cost efficiencies. With the push to become less reliant on fossil fuels, alternative fuel boilers provide a way for plant managers to save money on fuel sources as well as meet tightening emission regulation standards [7].

change to multi fuel operation working with alternative fuels - including landfill wastes, wood or hay materials, rubber, rice husk, sawdust, and plant by-products. because lowered emissions and operating costs. In many industries used multi-fuel power boilers to make cost effective steam for process use and on-site electrical generation. In addition to fossil fuels (gas, oil, and coal) it is common that these units be fed with alternate fuel streams such as biomass, waste wood, waste liquids, refinery off gases, biogas, excess Hydrogen, Coke Oven Gas (COG), or Blast Furnace Gas (BFG). In today's competitive business environment, it is critical that multi-fuel boiler operation be optimized such that steam is produced for the least cost possible [7]. Operation of a multi-fuel Boiler is more difficult by several orders of magnitude when compared to running a unit fired with only fossil fuels. Operating issues vary from site to site, but there are a number of problems that are seen in many places:

- Alternate fuel availability is poor and subject to frequent interruption.
- Alternate fuel Btu content varies significantly and quickly.
- Boiler emissions performance limits operation.

ENERGY MANAGEMENT FOR BOILER EFFICIENCY.

In a boiler the has to many energy loses. so that energy management helps to prevent energy loses and boiler efficiency how every typically boiler maintains include these energy management with its user guides. boiler cannot give 100% efficiency. Heat lose in flue gasses, radiation and convection lose; blowdown heat losses are some main heat losing ways. There have several techniques use to manage energy in a boiler. Proper boiler operations, reclaiming boiler system heat losses, boiler use and sizing Distribution system losses, etc.

Proper boiler maintains

mainly boiler should be very cleanly. Practically, any fuel, deposits very small amount on the fireside of the tubes it seems to reduce heat transfer. And also, water cleaning system is very important. Without water treatment boiler get in to damage and reduce efficiency highly. It's also causes to deposit unnecessary things (minerals) from water. When increasing this thickness between water and fire it directly reduces boiler efficiency. Boiler blowdown is other main thin in boiler maintain. When blow down, it wastes huge energy if can adjust the blowdown periods without harm it is cause to prevent energy loss and also keep unwanted air out in fire chamber helps to make complete fuel combustion. It can reduce fuel usage in boiler [8].

reclaiming boiler system heat losses

in this part heat exchangers can be used to maximize boiler efficiency. It can heat the water, before enter to the boiler. (preheating boiler feed water) tis is called economizer. Typically, it can increase efficiency by 3%-4%. Condensing economizers can increase the effectiveness of reclaiming flue gas heat efficiently.

boiler use and sizing

boiler use and sizing is very useful. if boiler Face to seasonal demand or other variation of demand, it causes to energy loss. For a example, huge boiler works with below 40 % output ratio, that boilers not work with fully efficiently. Therefore, choosing a suitable boiler is very important.

Distribution system losses

In the steam distribution system having linkages from fittings, trapping in pipes can cause to large energy losses. Therefore, distribution system should be with proper condition.

HEAT RECOVERY FOR BOILER OPTIMIZATION

In industrial waste heat is the energy that is generated in industrial processes which is not put into any practical use and is wasted or dumped into the environment. Sources of waste heat transfer through conduction, convection and radiation from equipment, equipment and processes heat discharged from combustion processes. This wastage can be preventing through various waste heat recovery technologies to provide valuable energy sources and decrease the overall energy consumption. Heat loss can be classified into high, medium and low temperature grades. Waste Heat Recovery systems are introduced for each range of waste heat to allow the most optimum efficiency of waste heat recovery to be obtained.

High temperature waste heat recovery (WHR) consists of recovering waste heat at temperatures greater than 400°C, the medium temperature range is 100–400°C and the low temperature range is for temperatures less than 100°C [9]. Usually most of the waste heat in the high temperature range comes from direct combustion processes, in the medium range from the exhaust of combustion units and in the low temperature range from parts, products and the equipment of process units.

The quantity or the amount of available waste heat can be calculated using the equation shown below [9]

$$\mathbf{Q = V \times \rho \times Cp \times \Delta T}$$

Q is the heat content in k Cal
V is the flow rate of the substance in m3/hr
ρ is density of gas in kg/m3
Cp is the specific heat of the substance in k Cal/kg °C
ΔT is the temperature difference in °C

Depending on the type and source of waste heat and in order to justify which waste heat recovery system can be

used, it is essential to investigate the amount and grade of heat recoverable from the process. Classification and Application In considering the potential for heat recovery, it is useful to note all the possibilities, and grade the waste heat in terms of potential value as shown in the following

1. Heat in flue gases
2. Heat in vapor streams
3. Heat losses in cooling water
4. Heat losses in providing chilled water or within the disposal of chilled water
5. Heat in gaseous and liquid effluents leaving process.

We should consider following areas when Developing a Waste Heat Recovery System
a) Sources and uses of waste heat
c) Availability of space
d) Any other constraint, such as dew point occurring in an equipment's etc.

After this, the next step is to select suitable heat recovery system and equipment to recover and utilize the same. Economic Evaluation of Waste Heat Recovery System is need to find the selected waste heat recovery system on the basis of financial analysis for investment, depreciation, payback period, rate of return etc. In addition, the advice of well-trained consultants and operators must be obtained for rational decision [8].

There are many different heat recovery technologies available which are used for capturing and recovering the waste heat and they mainly consist of energy recovery heat exchangers in the form of a waste heat recovery unit. These units mainly comprise common waste heat recovery systems such as air preheaters including recuperates, regenerators, including furnace regenerators and rotary regenerators or heat wheels and run around coil, regenerative and recuperative burners, heat pipe heat exchangers, plate heat exchangers, economizers, waste heat boilers and direct electrical conversion devices. These units all work by the same principle to capture, recover and exchange heat with a potential energy content in a process [8].

Benefits of Waste Heat Recovery

Recovery of waste heat has a direct benefit on the efficiency of the process. This is caused to reduction in the utility consumption & costs, and process cost.

Indirect Benefits:

a) Prevent pollution: A number of dangerous gases like carbon monoxide gas, sour gas, carbon black off gases, oil sludge, Acrylonitrile and other plastic chemicals are releasing to atmosphere

b) Reduction in equipment sizes: Waste heat recovery prevent the fuel consumption, which cause to reduction in the flue gas produced.

c) Reduction in auxiliary energy consumption: Reduction in equipment sizes gives additional benefits is reduction of auxiliary energy consumption like electricity for fans, pumps etc.

BOILER EFFICIENCY IMPROVEMENTS

The thermal efficiency of the boiler can be defined as the ratio of the heat output, which is effectively used for the process and heat input which is supplied by the fuel [9]
The effectively utilized heat, which is used to generate steam, will decrease with time.
Boiler efficiency can be calculated by two main methods,

1. Direct method
2. Indirect method

Thermal efficiency reflects how the boiler vessel transfers the heat. usually excludes radiation and convection losses. Combustion efficiency generally indicates the ability of the burner to use fuel completely burn without generating carbon monoxide or leaving unburned hydrocarbons [10].

How to improve Boiler Efficiency

1.Feed water Temperature
To improve any system's efficiency, it is important to maintain the standard of all the inputs of that system. In boiler system, it is the feed water system plays an important role in the overall efficiency. for this, the feed water temperature to ensure boiler it is operated at high efficiency.

2.Supply of air
Air/steam is wants to ensure adequate fire is generated inside the burner through good combustion. therefore important to know the percentage of air/steam for complete combustion. For fuel fired marine boiler with register type burner 15-20% by weight of air is required for complete combustion [10].

3.Structural Importance
The boiler is a high-pressure machine generating high temperature steam for various purposes. The outer shell is an important part which not only contains the pressure but keeps the temperature of the flue gas inside the boiler for better heat exchanging ability.

4.Blow Down Control
Blow down should be done in water the test results are high in chloride or when high conductivity occurs. Blowdown is actually waste of boiler heat and efficiency. This reduces amount of high temperature water inside the boiler and addition of moderate temperature water from hot well.

CONCLUTION

Water treatment is very important thing for improve boiler operation and maintenance of boiler. Every industry

try to reduce maintenance cost, cost for fuel and initial cost. initial cost cannot reduce but maintenance cost, fuel cost can reduce. heat recovery , alternative fuel usage and energy management method reduce the fuel cost. heat recovery method is environment friendly because exhaust gas or whatever the things release to environment at low temperature. boiler design also important things to reduce cost all of these method improve boiler operations, boiler efficiency and reduce the cost.

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