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IMPROVING BOILER OPERATION WITHOUT ADDITIONAL CAPITAL INVESTMENT

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ABSTRACT

Boiler is the most widely-used combustion equipment as a steam generator in most of the energy intensive industries in Malaysia. As the cost of generating energy steadily increases, there is a need to operate a boiler properly so that the maximum amount of energy could be generated. In addition to that, less harmful polluting species discharged from the boiler could be achieved as nowadays there is an increasing concern of the environment degradation due to the inefficient operation of the combustion equipment. This paper gives a brief review on the simple and yet important practices that can be used to optimize the efficiency of the boiler performance without additional capital investment.

INTRODUCTION

Steam is one of the primary energy resources in most industries. It is used for processing, drying, washing and also generating electricity in power plants. Almost all industries in Malaysia produce steam using a boiler which is old and yet well proven technology. For efficient steam production it is essential that any individual in charge of the steam generator, especially a boiler man, be familiar with the process control and mechanism of a boiler. Unfortunately, any of the opportunities for obtaining substantial energy and financial savings are squandered for some of the reasons as stated below;

a) lack of awareness of the latest technology.
b) overall financial benefits are not always fully appreciated.
c) energy saving projects often take second place to other production-related expenditures.

In addition to the above, few are aware of the environment degradation due to the inefficient process of steam generation.

,For efficient combustion and hence steam production, the mechanical parts of the boiler must be operating properly. If the control devices such as valves and dampers are not doing their jobsgood control is impossible. The boiler itself can be a problem. Therefore, before considering other factors the equipment must be in good operating condition.

An efficient boiler performance not only ensures the production of the right quality of steam required but also enables the financial savings in terms of fuel and maintenance costs. In addition to the just-mentioned benefits, the harmful exhaust emissions discharged to the environment can be minimized.

Mechanism of Combustion Process

Combustion is the process of mixing fuel with oxygen to produce heat. Almost all commercial fuels contain carbon and hydrogen. The carbon will first react to form carbon monoxide which

in turn will react with additional oxygen to form carbon dioxide. The hydrogen reacts to produce water vapor). For most practical purposes, the nitrogen in the combustion air takes no part in the reaction and passes through the combustion process unchanged; in fact, small amounts of oxides of nitrogen may be formed which are of great concern from the viewpoint of environmental pollution, but this is not usually significant for energy calculations.

Boiler Efficiency

The boiler efficiency is defined as the ratio of the heat delivered by the system to raise steam to the heat supplied to it. This efficiency can be evaluated by using the results of only a few measurements (fuel flow rate, steam flow rate, enthalpy of exit system, temperature of inlet feed water and heating value of fuel). Manufacturers rate the efficiency of their boilers on the basis of fuel-to-steam efficiency. Boilers can also be rated by combustion efficiency, which is usually several points higher because it does not consider radiation, convection, and heat losses. Thus :

Combustion efficiency + (radiation + convection + blowdown heat losses) = true boiler efficiency.

The combustion efficiency is the effectiveness of the boiler and relates to its ability to completely burn the fuel. Some manufacturers report ratings as "thermal efficiency", meaning the effectiveness of fuel-to-water heat transfer through the boiler tubes. Fuel-to-steam efficiency (the ratio of heat output to heat input) is the correct figure to use when determining the fuel costs. It includes radiation, convection, and other heat losses.

DETERMINATION OF BOILER EFFICIENCY

Boiler efficiency can be determined using two physical techniques.

1. Direct technique

The efficiency of the boiler is obtained by measuring the input and output flowrates of fuel and steam, including temperatures, pressures and fuel composition. Calibrated instruments are used. From the heating values of the fuel, enthalpy of the steam and other data, the boiler efficiency is calculated.

2. Indirect technique

This technique measures the combustion efficiency indirectly. The test is performed by obtaining an exhaust-gas analysis (i.e O_2, CO_2, CO or smoke) and the exhaust gas temperature.

IMPROVING BOILER OPERATION WITHOUT ADDITIONAL CAPITAL INVESTMENT

The following section discusses briefly the simple but very useful methods of optimizing the performance of boiler operation. All methods suggested here require, unless stated, no additional capital cost.

Reduce Excess Air

To burn the fuel, a theoretical quantity of oxygen (and hence of air) is needed and this is known as the "stoichiometric equivalent". In practice, the mixing of fuel with air is never perfect and it is necessary to add extra air to complete the combustion. This is known as "excess air".

Boiler manufacturers usually recommend 10%-20% excess air for a scientific and very practical reason [1,2]. If they were operated at 0% excess air, any change in atmospheric conditions (humidity, temperature or pressure) could easily change the air flow from excess air into deficient air and drastically reduce boiler efficiency. Some operators see "no harm" in adding excess air because they think that their "two" responsibilities are to keep the boiler running and to decrease the appearance of smoke (if using liquid fuel) in the stack by diluting it with excess air. It is definitely wrong because too much air allowed to enter the combustion chamber at ambient temperature will contribute nothing to the process except to take away useful energy as sensible heat loss. A boiler operator should therefore know how much air is to be added and keep this to a practical minimum. 5-10% fuel savings are possible by controlling the excess air alone [3]. This may be done by taking regular stack gas samples and checking oxygen and carbon dioxide content. High oxygen (or low carbon dioxide) or excessive white smoke levels indicate high excess air, which may be detracting unnecessarily from combustion efficiency. High carbon monoxide or excessive black smoke levels are also an indication of inefficient combustion: generally, it suggests insufficient air. If however the high carbon monoxide is accompanied by moderate to high oxygen levels, there is indeed some problem of fuel/air mixing.
The CO in the flue gas (measured in ppm of CO) stays fairly constant at high excess air. However, as excess air is reduced below the optimum level, the CO content rises sharply. Smoke or unburned hydrocarbons appear in the stack. In calibrating a boiler, once determine the minimum amount of air required, add a little excess air (e.g. 5 - 10 % depending on the type of fuel used). Always determine CO content in gas-fired heaters. In oil-fired boilers, this is not necessary because smoke appears as soon as the excess air is around zero. Calibration of a boiler involves obtaining a curve of the excess air vs. smoke for oil-fired boilers and excess air vs. CO for gas-fired boilers. Then the minimum and cushion excess air are determined from the curve. When air falls below the stoichiometric value, the unburned hydrocarbon present can lead to explosion [3].

Reduce Flue Gas (stack) Temperature.

It is desirable to reduce the flue gas temperature to a minimum for optimal efficiency. However, the flue gas temperature should be kept above the dew point of sulfuric acid if the fuel used contains sulfur element. Basically, there are three causes of high flue gas temperature;

a) Excess fuel (overfiring) : If there is excess fuel , the fuel rate can be decreased to decrease the temperature and yet the required steam production be maintained. If steam production suffers, this is not a good solution to the problem.

b) Fouled heat transfer surface: Fouling which occurs on either fireside or waterside surface area of the tubes increases the thermal resistance and therefore decreases the heat transfer rate.

i) On fireside : When firing especially solid or liquid fuel soot or vanadium based deposits are always the cause for fouled tubes. The deposition of this material will eventually decrease the heat transfer rate and this is noticeable when the flue gas temperature increases with time. Therefore the fireside tubes need regular cleaning to remove sooty and metal deposits. Soot blowers of various kinds are widely available in the market. Alternatively, specialized additives can be added to the fuel oil used to minimize soot deposits.

ii) On waterside: Water from rivers, ponds and wells cannot be used in a boiler without previous treatment. Unless the boiler feed water is treated properly, the life of a

boiler will be shortened very quickly. Untreated feed water can be a source of inorganic scale and deposits which will increase the thermal resistance on the tube surface. Completely pure water, ready for use in a boiler, does not exist. Therefore feed water treatment can be effective in maintaining clean heat transfer surfaces and hence increases the heat transfer rate (and hence lowering flue gas temperature).

c) **Insufficient heat transfer surface area:** Insufficient heat transfer surface area might be responsible for high flue gas temperature. If this is the reason there are two alternatives (whichever economically feasible) that can be used to solve the problem;

i) An economiser that uses the heat energy from the flue gas should be considered. An economiser both lowers the flue gas temperature and raises the temperature of the feed water to the boiler. Economisers are expensive, and an economic analysis is recommended before installing one.

ii) Relocating the combustion air intake duct in such a way that the heat energy from the flue gas can be used to raise the air temperature. If this is feasible installing an air preheater across the flue gas line is recommended.

Reduce Boiler Blowdown

Excessive blowdown due to poor water treatment or poor operating practices can be a source of inefficient boiler operation. The hot blowdown stream has energy that is loss unless it is recovered. The water loss during blowdown has to be made up. If the solid particulate in the make-up water is not well treated, the water in the boiler must be frequently blown down to prevent the boiler from plugging. There are two types of blowdown; (1) The mud blowdown - designed to remove heavy sludge at the bottom of the boiler and (2) continuous blowdown - designed to remove solid dissolved in the water. These can be reduced if the feed-water quality is regularly checked and the appropriate water treatment is done. Regular checks of total dissolved solids (TDS) and alkalinity in the blowdown will determine how much blowdown is really necessary.

Alternatively, one can recover the waste-heat energy from the blowdown by using it to preaheat the feed water. This can be achieved by adding a flash tank to the system. The blowdown is flashed by lowering the pressure in the flash tank; the steam produced is then vented into the feed water to the boiler.

Reduce Boiler Pressure

Some boiler operators do not realise that they are running the boiler at a pressure higher than necessary. If they do realise , not many are not fully aware that reducing the operating pressure could have an impact on fuel savings. Lowering the operating pressure results in the following savings;

a) lower flue gas temperature due to improved heat transfer.
b) lower heat losses from the boiler and piping.
Ic) less steam leaks due to lower steam pressure.

However the following precautions must be taken into consideration as a result of reducing the boiler operating pressure;

a) boiler circulation may be upset.
b) relief valves may have to be changed.
c) mud blowdown may have to be timed so that steam demand is at its lowest point.

Alternatively, if more than one boiler is available, consider running one at low pressure for low-pressure requirement and run the other boiler at high pressure.

Increase Fuel Oil Temperature

The boiler nozzles are designed to facilitate the blending of air and fuel so that combustion efficiency will be optimised. The fuel will be properly atomised if its viscosity is right. If the fuel is too viscous or too thin, the fuel-air blend will suffer, resulting in lower combustion efficiency. The oil viscosity can be controlled by preheating to the recommended temperature before combustion takes place.

Optimise Boiler Operation

Boiler efficiencies vary with boiler design, load, age, and many other factors. Peak operating efficiency occurs at a load less than 100% because of interaction among stack temperature, excess air flow and surface radiation losses. Therefore the most efficient boilers should be used most of the time. This can be accomplished by never operating all boilers at reduced load or performance; scheduling boilers for specific needs according to their efficiencies and load; and considering purchasing smaller boilers. Boiler selection can be done by obtaining the efficiency of each boiler vs. load; analysing the steam peak demands; coordinating boiler and plant operation; and adjusting each boiler to operate at peak efficiency.

Reduce Steam Leak and (Stop) Steam-Trap Leaks

Checks on steam piping leaks should be made regularly as a small leak can turn into big losses. Regular checks must also be performed on steam trap to ensure there are no steam trap malfunctioning. The proper installation and care of steam traps by their manufacturers must be followed.

CONCLUSION

Simple and yet useful methods of optimising the boiler operation have been briefly discussed. With little knowledge of the steam production and boiler operation mechanism coupled with little time taken to have all the boiler operating equipment conditions routinely checked, tremendous savings of energy (bill) could be realised.

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