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Improving the Efficiency of the Boiler

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Abstract— A boiler or steam generator is a device used to create steam by applying heat energy to water. The flue gas temperature at the outlet of air preheater which-is the final regenerative equipment is higher than the design temperature and a proportionate quantity of heat is carried away by the flue gases to the atmosphere. A proportionate quantity of fuel can be saved by utilizing the waste beat from the flue gases. Due to this saving the efficiency of the boiler can also be increased considerably. A heat exchanger is used to recover the waste heat. Waste heat from the flue gas can be used to heat some portion of the feed water coming out from condensate extraction pump. Feed water is heated by passing it through the heat exchanger. Recovery of waste heat is done by placing heat exchanger in the flue gas, duct after air preheater stage. This is done without disturbing the original system.

I. INTRODUCTION

A boiler is a closed vessel in which water are other fluid is heated. The fluid is don't necessarily boil. The hot water or steam under pressure is then used to transferal the heat to a process

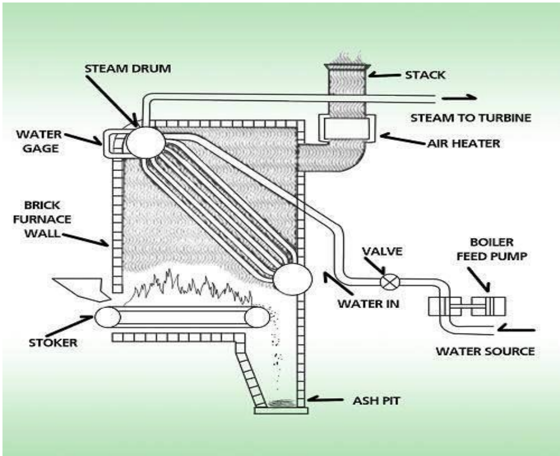

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Fig. 1 Boiler

There are two general types of boilers fire-tube and water-tube. Boilers are classified as high-pressure or low-pressure and steam boiler or hot water boiler.

Heater is one of the high vitality utilization hardware to give boiling water/steam for the group what's more, industry the record of fuel utilization is around 400 million to 500 million tons of standard coal consistently. The genuine warm proficiency of coal-let go kettle is just 60%-65%, which is lower than the worldwide level of 15% to 20%. There are some regular issues of heater burning, for example, deficient ignition and high carbon content in slags Local and outside scientists directed countless because of the heater warm effectiveness, these examinations center around overabundance air coefficient , deplete warm misfortune and strong deficient burning warmth loss ,connected the idea of vitality and exergy productivity in modern boilers, the analysts found that the burning chamber adds to the predominantly exergy misfortune in the kettle framework. Set up a numerical model of twofold drum steam heater, the outcomes demonstrate that herringbone raise curve can quicken the start what's more, burnout contrasted and regular back. built up a double molecule distance across demonstrate for the stratified ignition of a chain stoker, the outcome demonstrates that the double molecule measurement model can better reproduce the ignition attributes of the coal bed after a stratified coal shelter has been furthermore introduced. Set forward an arrangement to remodel chain-grind evaporator with pummeled coal consolidated ignition, and the warmth productivity moved forward.

II. LITERATURE REVIEW

Srinivas et al. [1] studied the optimum configuration for single pressure (SP), dual pressure (DP) and triple pressure (TP) heat steam generator (HRSG) to improve heat recovery and exergy efficiency of combined cycle. Deaerator was added to enhance efficiency and remove dissolve gases in feed waterIt is concluded that optimum pressure ratio for compressor with SP, DP and TP effects in heat recovery are 8, 10 and 12 respectively at 12000 C of gas turbine inlet temperature optimum deaerator pressure is obtained at 1.3, and 5 bar for SP, DP and TP levels respectively at steam turbine inlet pressure of 200 bar. Similarly at 200 bar of HP pressure for DP and TP, steam reheated demands 100 bar to maximize exergy efficiency for combustion chamber. Parametric analysis exhibits that gain in efficiency from single pressure heat recovery to DP and TP recovery increasing with diminishing rate.

Mitre et al. [2] studied the effect of operational condition on pollutant (CO, CO_2, SO_2, No) emission level, waste heat and waste water of a combined cycle natural gas and steam power plants. The chemical process simulator was used for modeling and simulation. This study clearly shown that the absolute quantity of pollutants emitted is high. Also it was possible to verify that the unit operation in the condition of minimal emissions regarding the maximum possible, and thus a reduction or elimination of such pollutants is not possible. It can be observed from the above study that the ideal condition for exergy productivity is to operate with a fuel air ratio as stoichiometric one. The first constraints to this ideal is the mechanical conditions of the turbine, which can be operate at the corresponding combustion gas exit temperature so a stoichiometric ratio in the range is used, and these conditions make the process viable and minimize pollutants production (CO and NOx). These operational conditions are the optimal considering environmental concerns. The CO_2 being a product, is maximized in the process, so there is no need to search for methodologies to minimize their production, but there is for technologies for their capture and uses parallel to the process.

Yadav et al. [3] emphasis on development of gas turbine related power plants such as combined cycle and steam injected on increasing the plant efficiency and specific work while minimize the cost per KW and emission. The work deals with the thermodynamic analysis of inter cooled gas steam combined analysis injected power plants. There exist an optimum intercooling pressure which influences the performance with reference to plant efficiency. Author conclude that the intercooling has a beneficial effect on both plant efficiency and specific work if the optimum intercooling pressure ratio is chosen 3 to 4. As expected the higher TIT and rpc results in better performance. However due to transpiration air cooling their existing an optimum rpc at higher TIT in the case combined cycle but it is not observed in the steam injected cycle. The blade requirement is less with low inter cooling pressure ratio. As rpc increase the coolant requirement increases for same TIT. The evaporator type of intercooler is superior to surface type by percentage point. The plant efficiency of intercooled steam injected cycle 1000 K. The exergy analysis reckons the losses in the component and it is maximum in combustor following by gas turbine in combined cycle where as it is following by HRSG in steam injected cycle.

III . PHYSICAL MODEL OF BOILER SYSTEM

Evaporator framework is for the most part made out of wind, smoke and steam-water framework. Sustain pump, warm exchangers, drum, air blower, heater, fireplace are the principle parts of the framework are shown in the figure 2. Faucet water is provided to heater through the bolster pumps, and after that warmed by flame. Frosty air is drawn into the burner through a blower, frosty air and fuel are blended in the burner and after that ignition. Fuel gas is released into the fireplace. Where q_2 (%) is the exhaust gas heat loss, q_3 (%) is the gas incomplete combustion heat loss, q_4 (%) is the solid incomplete combustion heat loss, q_5 (%) is the boiler radiating heat loss, q_6 (%) is the boiler slag heat loss. q_2 is the main loss of the thermal efficiency, the value of q_3 and q_5 are 0.005 and 0.02193 because of the capacity of the boiler system is fixed, q_4 and q_6 have little effect on the thermal efficiency.

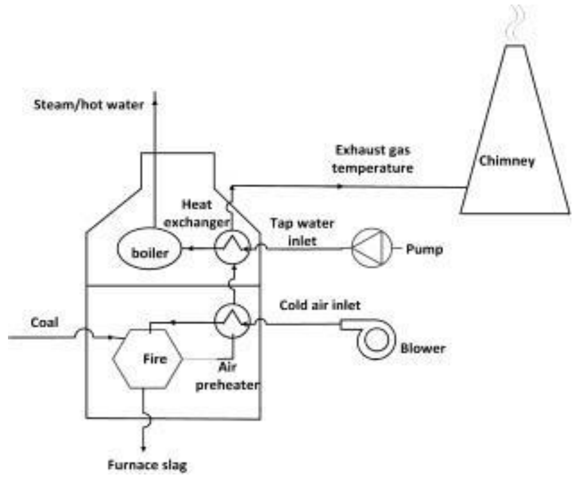

Fig. 2 Physical model of boiler system.

IV. FACTORS AFFECTING OF THERMAL EFFICIENCY OF BOILER

The key factors affecting the boiler heat loss and efficiency are superheating surface area, excess air coefficient, inlet gas and exhaust gas temperature, etc.

The exhaust gas temperature has a great impact on the exhaust gas heat loss (q_2) of boiler system, the increase of exhaust heat loss will result in the decrease of boiler thermal efficiency (η).q_2 increases with the increasing of t_{py}; q_2 increases about 1% and η reduces by 1% when the exhaust gas temperature increases 10-15^{o}C, because the high temperature flue gas takes away a lot of heat loss. Boiler exhaust gas temperature is related to the boiler heating surface. Reducing exhaust gas temperature can decrease exhaust smoke heat loss and increase the boiler tail-heating surface. Exhaust gas heat loss has the largest percentage 5-10% of all heat losses of pulverized-coal boiler system.

The effect of excess air coefficient (α) on the exhaust gas heat loss (q_2) and thermal efficiency (η). As the excess air coefficient increases, the exhaust heat loss will increase and boiler thermal efficiency will decrease. The thermal efficiency decreases 0.8%-1% when the excess air coefficient increases 0.1, because of the incomplete combustion of fuel.

Usually when increasing α, q_2 will increase and gas incomplete combustion heat loss (q_3) will decrease, and solid incomplete combustion heat loss (q_4) will decrease first and then increase. Therefore, the sum of the three losses will decrease first and then increase as α increasing. The best value of α should be made the minimum of the three losses.

The influence of excess air coefficient on the boiler efficiency and exhaust heat loss.

The effect of inlet cold air temperature on the exhaust gas heat loss (q_2) and thermal efficiency (η). When increasing inlet cold air temperature, exhaust gas heat loss decreases and Thermal efficiency increase. When the inlet cold air temperature increases 10^{o}C, the boiler exhaust heat loss will decrease by 0.8%-1% and boiler thermal efficiency will increase by 0.8%-1% because of high efficient of the boiler combustion.

The of slag carbon content on the solid incomplete combustion heat loss (q4) and thermal efficiency (η). When increasing slag carbon content, solid incomplete combustion heat loss increases and thermal efficiency decrease. When the slag carbon content increases from 8% to 18%, thermal efficiency decreases by 2%.

V. PERFORMANCE INDEXES OF SEVEN OPTIMIZED SCHEMES

Seven optimal boiler schemes are designed from the view of operability principles. The measurements include equipment technologies and parameters adjustment are shown in the table 1. The first optimized scheme is to reduce the exhaust gas temperature to 190°C and slag carbon content to 12.23 % by using stratified combustion technologies. The second optimized scheme is to increase the inlet cold air temperature to 70°C and reduce slag carbon content to 17 % by heat transfer technologies and adding the air preheater. The third optimized scheme is to reduce the heat loss coefficient to 0.5 by increasing the thermal insulation technologies on the boiler system. The forth optimized scheme is to reduce the exhaust gas temperature is to 200°C and slag carbon content to 13% by using stratified combustion technology and enhancing heat transfer technologies. The inlet cold air temperature is preheated to 55 °C. The fifth optimized scheme is to increase the boiler inlet cold air temperature to 55 ^{o}C and reduce the heat loss coefficient to 0.5 by employing enhancing heat transfer technologies and increasing the thermal insulation technologies. The exhaust gas temperature increases to 235°C. The sixth optimized scheme is to reduce the boiler exhaust gas temperature to 195 °C and slag carbon content to 13% by using stratified combustion technologies and increasing the thermal insulation technologies. The heat loss coefficient reduces to 0.5. The seventh optimized scheme is to reduce the boiler exhaust gas temperature to 170°C and slag carbon content to 12% by using stratified combustion technologies, enhanced heat transfer technologies and thermal insulation technologies. Inlet cold air temperature is preheated to 50°C, and heat loss coefficient reduces to 0.7.

Table.1 Performance indexes of seven optimized schemes

Optimized scheme	Thermal efficiency (%)	Exhaust gas temperature (°C)	Excess air coefficient (α)	Slag carbon content (%)
Original system	71.2	231.5	2.434	18.95
Optimized scheme I	77.9	190.5	2.434	12.23
Optimized scheme II	75.6	245	2.434	18.95
Optimized scheme III	74	231.5	2.434	18.95
Optimized scheme IV	79.77	200	2.434	13
Optimized scheme V	76.55	235	2.434	18.95
Optimized scheme VI	78.65	195	2.434	13
Optimized scheme VII	83.2	170	2.434	12

VI. ENERGY SAVING POTENTIAL ANALYSIS OF BOILER SYSTEM

The energy saving potential comparisons between original and optimized systems is calculated. The economics, electricity consumption and CO_2 emission reduction of different systems. Scheme VII is the best optimized scheme.

The seventh optimization scheme is the best choice for the boiler system; the fourth, sixth and first scheme is inferior to the first one in terms of energy saving potential, but the difference is not big; the second and fifth scheme have little difference in terms of energy saving potential; the third optimization scheme is the last choice, which just saves 85 tons of coal and 220 tons of CO_2 emissions annually.

Stratified combustion technologies and adding air preheaters have more significant effluence on the system optimization. Heat losses preservation measurements are little ineffective compared with stratified combustion technologies and adding air preheaters.

VII. HEAT RECOVERY FROM FLUE GAS FOR FUEL DRYING AND AIR HEATER SYSTEM

The use of flue gas to increase boiler efficiency was divided into two parts, namely, applying the recovery heat to dry the fuel and applying it to preheat the air before entering combustion chamber, Our fuel drying system was working with fuel with moisture content around 30 - 40 wt% in a direct screw conveyor tube. Conveying coal from the stack to the combustion chamber was in 2 stages, first by a screw conveyor, which lifted the coal on a floor and passed it to the screw feeder. The latter fed coal into the combustion chamber. . Fuel drying system connected exhaust pipe behind the boiler with the screw conveyor in the first stage where the temperature of flue gas was between 120°C - 150°C. This was blown directly on to the coal in the screw conveyor.

The design of the heat exchanger was based on the single-pass cross-flow with both fluids unmixed. Cool air was used as the flowing fluid in the tube and hot flue gas was a fluid outside the tube.

Automatic combustion control was achieved by measuring the amount of Oxygen gas (O_2) from the flue gas stack in order to find if the amount of air was adequate for combustion. In general, the measured ratio of O_2 after combustion of rigid fuel is between 3% - 7%. Any percentage higher than this means too much air for combustion and the FD fan speed should be lowered so that combustion air is less. To automatically control O_2, we need to know the correlation between the amount of air needed for real combustion in the boiler and the amount of O_2 remained from combustion. This correlation is used as the control basis. The correlation value between real amount of combustion air in the boiler and the amount of O_2 can be found from the experiment. We adjusted the frequency values of the FD fan inverter control and recorded the oxygen percentages measured at the flue gas stack.

VIII. HEAT RECOVERY FROM FLUE GAS

How much moisture can be removed by fuel drying with recovery heat depends on the amount of flue gas used in the drying, the rate of fuel feed into the screw conveyor which in turn depends on the steam loading capacity of the boiler at that particular time, and the initial moisture content of the fuel before the drying process begins. If coal moisture content is high, it may not be effectively removed when compared to coal with low moistrue content

IX. CONCLUSIONS

In this paper "EFFICIENCY IMPROVED BY RECOVERING WASTE HEAT FROM FLUE GAS" has got a wide application in energy conservation.

By providing heat exchanger for recovering the waste heat from the boiler, it has got a wide range of advantages like reducing heat losses, fuel conservation and payback period. The final result of project area follows.

- A suitable heat exchanger is designed
- Thermal analysis is done on heat exchanger
- Heat losses can be effectively reduced upto 90%
- The coal saved nearly 3.7 tonnes per day
- The experiment on automatic combustion control was based on the Fuzzy Logic Control Algorithm which controlled the FD span input.

X. NOMENCLATURE

CO -Carbon monooxide
CO_2 -Carbon dioxide
SO_2 -Sulphur dioxide
NO -Nitrous oxide
q_2 - Exhaust gas heat loss
q_3 -Gas incomplete combustion heat loss
q_4 -Solid incomplete combustion heat loss
q_5 -Boiler radiating heat loss
q_6 -Boiler slag heat loss
α -air coefficient
η -thermal efficiency

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