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Installation of Condensing Economizer to improve the efficiency of Natural Gas Fired Boiler

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Abstract

In this study, Condensing economizer is used to increase the thermal efficiency of boilers by recovering sensible and latent heat from exhaust gas. A considerable amount of waste heat in boiler flue gases is in the form of latent heat of water vapor. The energy cannot be recovered until the flue gases are cooled to a temperature below than the dew point. These economizers are currently being used commercially for this purpose in a wide range of applications. Performance is dependent upon application-specific factors affecting the utility of recovered heat. Condensing units also capture the flue gas particulates. In this paper, the primary focus is on introduction of condensing economizer's for efficiency improvement of natural gas fired boiler. The secondary focus of this paper is to reduce or to control the particulate emission from natural gas fired boiler.

Keywords: Condensing economizers, waste heat recovery, sensible and latent heat, natural gas fired boiler

1. Introduction

Natural Gas (NG) is a very common and clean fuel which is widely used by various industries for steam generation. Natural gas is also well known for its combustible behavior and the most nonpolluting and easy-to-combust fuel due to its low C/H ratio. Therefore, it has always been in great demand not only for various industrial uses but also for many domestic applications including usage in car, bus etc. to meet stringent norms of the environment. Moreover, it is easy to handle.

In the operation of pressure boiler, there introduce three types of heat losses; a) conductive and convective heat loss through insulation and radiation. b) Heat loss through blow down and c) heat loss through exit flue gas but also for many domestic applications including usage in car, bus etc. to meet stringent norms of the environment. Moreover, it is easy to handle. Though, energy loss through insulation, radiation and blow down is minimum, large and more amount of heat energy is waste with the flue gas exited in the

atmosphere at high temperature. Recovering this heat energy from this flue gas from various types of pressure boilers is a real challenge.

Normally, net calorific value (NCV) of natural gas varies is in the range of 8500- 8600 Kcal/Sm³. Having flue gas temperature in the range of 110-115oC in a natural gas fired boiler, boiler efficiency varies in the range of 91-92%. Flue gas temp of different conventional steam boilers using different fuel is given in Table 1.

Due to change in Govt. policy and huge demand supply gap, natural gas price had radically increased from beginning 2009. Price increase was further coupled the volatile price of liquefied natural gas (LNG) which was being imported to meet the excess demand. In Indian scenario, both supply and cost of natural gas had changed considerably due to dramatic increase in the consumption in various segments.

Table1. Heat recovery from flue gas from different types of boilers

Steam Boiler using different fuel Flue Gas Temp

1	Coal Fired Boiler	160-170oC
2	Furnace Oil Fired Boiler	170-180oC
3	Conventional Natural Gas fired Boiler	110-115oC
4	Condensing Boiler, Natural Gas fired	53-56oC

This had widened the gap of demand and supply leading to significant price increase of natural gas. Therefore, there was no other option, but to think differently to reduce energy cost the overall. Boiler being one of the major energy consumption points, the primary focus was on increasing the boiler efficiency and reducing natural gas consumption and therefore the energy cost for steam generation to retain the leadership position.

To achieve the stated objective, it is necessary to explore and provide a techno-commercially feasible solution for having improved boiler efficiency. Installation of a condensing boiler is the solution found.

Boiler efficiency

Any petroleum fuel contains constituents like Carbon (C), Hydrogen (H), Oxygen (O) ,Sulphur (S), Nitrogen(N) and water or moisture (H₂O) etc. in different proportions. Combustion of C, H, and S in presence of air releases energy due to exothermic nature of the reaction. Gross Calorific Value (GCV) is defined as the energy released due to combustion of per unit mass of fuel. It is generally expressed in Kcal/Kg or Kcal/Sm³. Combustion of Hydrogen (H) present in fuel forms water which remains in vapor form in the flue gas; let's call this mass as x₁. Moisture/water present in the fuel also evaporates and remains in water vapor form in flue gas; let's call this mass as x₂. x₂ is normally very less in natural gas. Combustion also carries over the moisture contain along with air which also remains in flue gas in vapor form. Let's assume this mass as x₃. Therefore, total

water vapors present in the flue gas are x₁+x₂+x₃. For evaporation of this total water and reach to flue gas temperature requires energy, known as enthalpy, which is taken away from the gross energy released during combustion process. As a result, heat carried away by the water vapor in the flue gas is not available for steam generation. It is directly lost in the atmosphere. The air and the combustion products other than water (CO₂, CO, NO_x) and nitrogen also take away a significant amount of heat.

Hence, GCV minus heat lost in the water vapors, inserts and combustion products per unit mass of the fuel is called Net calorific Value (NCV). Boiler efficiency is calculated based on NCV of the fuel as heat carried or lost with water vapors is any way not available for heat transfer. It is NCV which is available for heat transfer in the boiler for steam generation. Condensing boilers use heat from exhaust gases that would normally be released into the atmosphere as flue gas. To use this latent heat, the water vapors from the exhaust gas is turned into liquid condensate through heat exchange of cold demineralized feed water which is preheated in a specially designed condensing economizer. Due to this process, a condensing boiler is able to extract more heat from the fuel it uses than a standard boiler. It also means that less heat is lost through the flue gases. Flue gas temp coming out from the boiler at 330-340oC is passed through the 1st stage non-condensing economizer and decreased to 170-175o C. Then it is again passed through 2nd stage non-condensing water pre-heater where temp is reduced to 80-85o C. Finally it is passed through a 3rd stage condensing economizer where final temp of the flue gas is further reduced down to 53-55oC by preheating the boiler feed make up water fed at 31oC. Reducing the flue gas temp from 330 to 55o C is very unique in industrial boiler operation.

This serves two purposes at a time.

- 1. It helps in improving thermal efficiency of natural gas fired boiler by lowering Natural Gas consumption for unit production of steam.**

A schematic arrangement diagram of condensing boiler showing reduction in flue gas temp in stages is given below. Thermal efficiency of the natural gas fired boiler at different flue gas temperature is shown in the Fig 1. At 55oC flue gas temp, boiler efficiency is ~ 100 % compared to 91-92 % in a conventional boiler having flue gas temp of 110- 115oC. At 45o C flue gas temp, boiler efficiency can be as high as 103% showing in fig. Estimated natural gas saving per year at different capacity condensing economizer is given Fig 2 based on performance of condensing boiler. NG saving can be increased up to 4 to 5 Sm³ per MT of steam generation depending of the lower flue gas temp and efficient design. Installation of 24 TPH condensing boiler had gave the saving of 550000 Sm³ natural gas per year @ 80%.

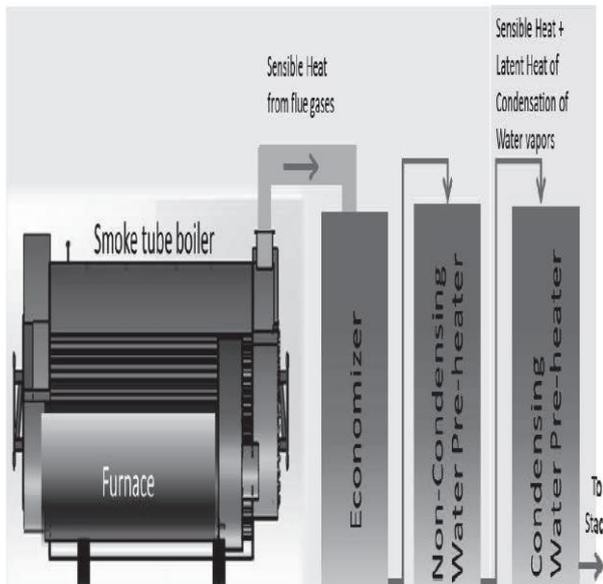


Fig.1 Schematic arrangement diagram

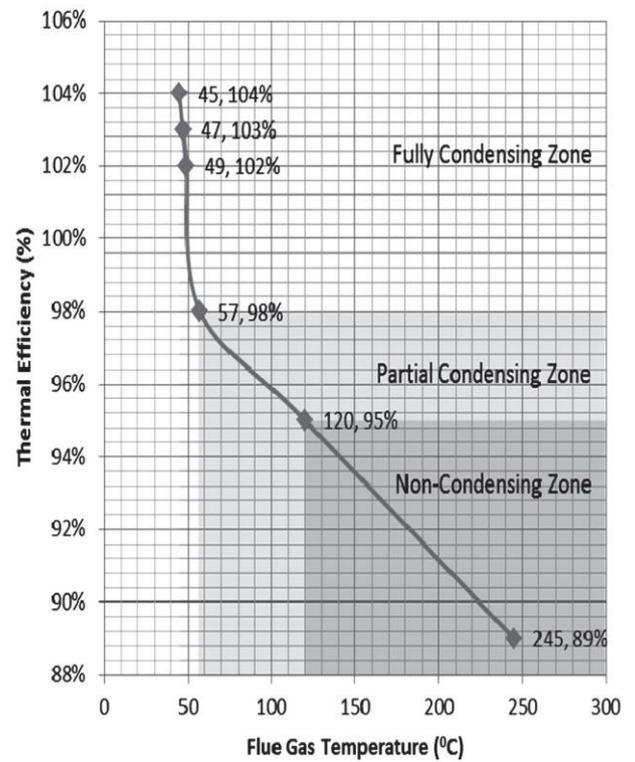


Fig.2 Graph of Thermal Efficiency vs. Flue gas temperature

Load and value addition of more than 1.7 Cr on account of only H ratio, burning of 1 mole methane (Molecular weight of methane is 16) generates 2 moles of water (Molecular weight of water is 18). Therefore, combustion of 16 kg methane generates 36 kg water on complete combustion with sufficient air which is carried away with the flue gas in the form of vapors. This water is generally lost in the atmosphere. Cooling down the flue gas temp below dew point and recovering the water from the flue gas directly leads to conservation of natural resource. Latent heat of condensation of water from flue gas is indirectly used for preheating the boiler feed water entering @ 31oC. About 60, 00, 000 liters water is recovered per year by condensation from flue gas at flue gas exit temp of 55oC. This is almost 40 % water recovery from the flue gas .Condensed water is little acidic and pH varies in the range of 3-4. This water is used and recycled in the process for suitable use. Acidity is mainly due to presence of mainly weak carbonic acid formed by scrubbing of carbon di-oxide gas with condensed water at lower temp. This CO₂ energy conservation absorption process directly reduces greenhouse effect in the

atmosphere. The entire operation of 24 TPH condensing boiler is automatically controlled and monitored from a dedicated PLC system. Consumption of both natural gas and water recovered is measured real time using a flow meter installed on-line.

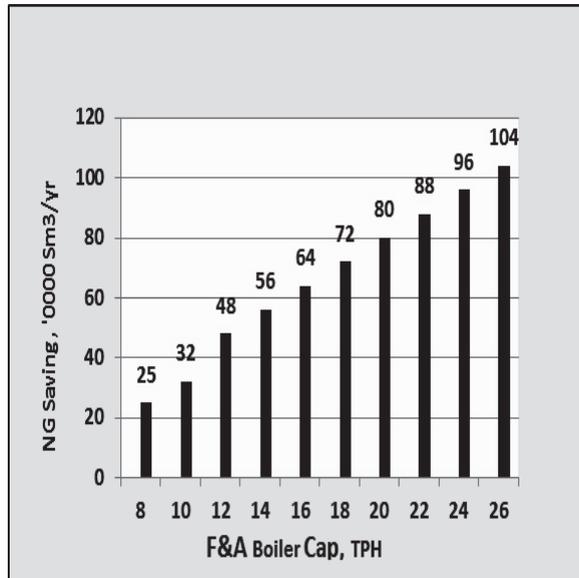


Fig 3.natural gas saving per year at different capacity

Table 2.Scenario before and after installation of condensing economizer in natural gas fired boiler.

Sr. No	Description	Before	After
1	Flue gas exit temp.at chimney	115oC	55oC
2	Water recovery from flue gas per annum(L)	0	60,00,000
3	Natural gas consumption per MT of steam, Sm ³	74	70
4	Natural gas saving per annum,Sm ³	0	5,50.000
5	Energy cost Saving per annum	0	200
6	Boiler thermal efficiency on NCV of fuel.	92%	100%

Challenges in installation of condensing boiler:

- 1) Selection of proper material for designing the condensing economizer in natural gas fired boiler for long life as it leads to low end corrosion due to acidic nature of the condensate and condensation of other acidic vapors such as NO_x or SO_x if any.
- 2) Chimney should be with proper MOC i.e. either FRP lined or AISI SS 304.
- 3) Independent condensate collection system and suitable use in the process with the by-pass arrangement of the condensing section to have flexibility in flue gas shift.
- 4) Pressurized de-aeration tank to remove dissolved oxygen from feed water by steam sparging

CONCLUSION:

Based on the above outcomes, following conclusions can be made.

1. Boiler efficiency can be increased > 100% depending of the temperature of condensate return.
2. Minimum 3 Sm³ natural gas can be saved per MT of steam generation vs. conventional boiler. NG saving can be increased up to 4 or 5 Sm³ per MT of steam generation depending of the lower flue gas temp and efficient design.
3. Highly energy efficient & eco-friendly.
4. De mineralized water recovery from flue gas leading to conservation of natural resource.
5. Reduction in CO₂ emission in the atmosphere.
6. Low ambient temperature due to lower flue gas temp in chimney (50-55o C).

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