

Circulation Analysis of A Water Tube Boiler In A Thermal Power Plant

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Abstract— The circulation ratio of a water tube boiler affects the efficiency of the power plant since the boiler has to operate in different operating conditions. The study of heat flux with the different modes of heat transfer, is necessary to evaluate the performance of any heat exchanger.

A boiler is basically a heat exchanger where the water flows inside the tubes and the flue gases flow outside the water tube which involves the phenomenon of departure from nucleate boiling and overheating of tubes. The boiler is usually designed after a detailed study of this circulation ratio is made at different conditions. This study is essential for ensuring optimum design of a Water tube boiler.

Keywords—Circulation Ratio, Water Tube, Temperature, Nucleate Boiling, Dryness fraction

I. INTRODUCTION

The circulation of boiler is the movement of either liquid water or a combination of liquid water or steam inside the water tube. The role of heat transfer of the two phase mixture is critical since it involves the phenomenon of departure from nucleate boiling.

The percentage of dryness fraction also has an impact on the circulation ratio since it involves the heat transfer at high temperature and pressure. The circulation ratio is one of the important design parameters as it varies with boiler operating pressure, the mass flow of the liquid water inside tubes, and the heat density normally termed as heat flux.

II. WATER TUBE BOILER

Water tube boiler is a heat exchange where water is circulated inside tubes and flue gases flow outside the tubes exchanging heat to water by conduction, convection and radiation. Depending upon the mode of circulation, the water tube boilers are classified into natural circulation and forced circulation boilers.

Forced Circulation boiler uses circulation pumps to ensure water and steam flow in the circuit. Natural Circulation boilers use the density difference to drive the circulation of water-steam mixture. The liquid water enters the economizer which preheats the water with the help of flue gases before leaving stack.

The preheated water enters the boiler drum which stores water temporarily and the generated steam is collected at the top. The cool water flows in pipes called downcomers and steam by the tubes termed as risers.

The liquid water inside the tubes gets heated and gets converted into water- steam mixture which rises to steam drum due to density difference. The saturated steam passes through another set of heat exchanger called super heater and superheated steam is obtained. The schematic of a water tube boiler is shown below in Figure No.1.

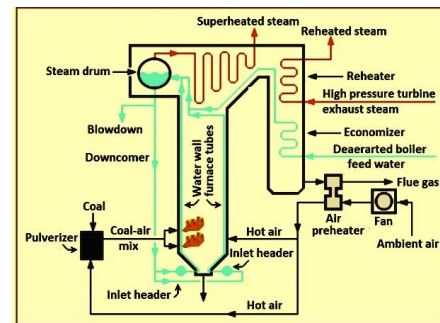


Figure No.1. Schematic of a water tube boiler

III. CIRCULATION ANALYSIS

Circulation ratio of the water tube boiler is defined to be the ratio of the total mass flow rate of two phase mixture circulating through the water tubes to the mass flow rate of dry saturated steam generated.

$$\text{Circulation Ratio} = \frac{\text{mass flow rate of Two - phase mixture in watertube}}{\text{Mass flow rate of dry steam generated}}$$

The circulation in an industrial boiler is the continuous supply of water to the boiler tubes in order to sustain the steam output without the process of super heating [1].

The models developed for water circulation in boiler to calculate the flow parameters like velocity, steam quality, rate of steam generation, void fraction, skin temperature, and finally circulation ratio is studied by Syed[2].

Lower circulation ratio in a tube can lead to various problems like phase stratification, departure from nuclear boiling, and two-phase instability.

The Natural circulation boiling circuits are successful in operation with 4 to 8 range of Circulation Ratio[3]. The investigation done to study the allowable and actual steam qualities to set apart thereby to avoid the departure from Nucleate Boiling [4-5].

The circulation rate is achieved as per design only if the mass flow rate of liquid water is adequate without starvation and typical range for various operating type of boiler is shown in Figure No. 2. below:

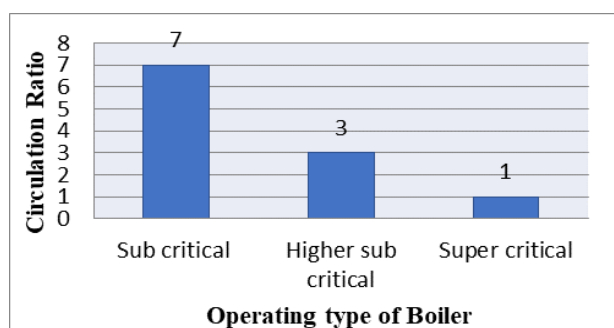


Figure No.2 Circulation Ratio for various Operating Type of Boilers

The instabilities during various stages of natural circulation systems like single phase, boiler inception and fully developed two flow have been observed [6-7]. Two phase flow has different resistance and driving forces embedded in each loop.

The driving force will be different due to height difference and variation in dryness fraction which changes from 0 to 1. The variation makes the system complex and hence the circulation analysis is quite useful for design of any type of boiler.

IV. TWO PHASE MIXTURE

The flow parameters which affect the flow distribution are the area of the header, the size and location of inlet port to the header, and the diameter of the header line. Since the water tube boiler operates at high temperature and pressure, the mass flow rate of steam and water circulation is very critical to prevent tubes from over-heating and starvation.

The tubes when over-heated, softens or ruptures in the water tube, bubbles of steam form in heated tubes called risers and the resulting steam and water mixture is lighter than the water at a lower temperature in unheated side of boiler and rises to steam drum at top of boiler as shown in Figure no. 3. The water flows from the drum downwards through the tubes at a lower temperature called the down comer and this cycle repeats.

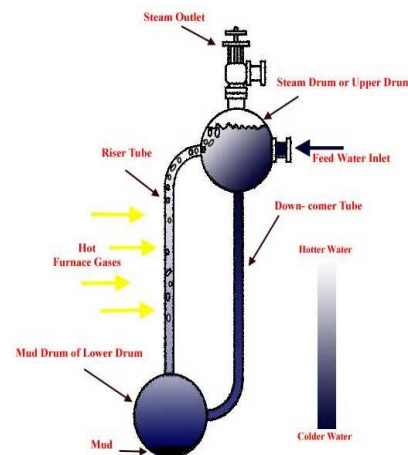


Figure No.3 Two phase mixture circulation in a water tube boiler

V. CONCLUSION

The water tube boiler is safe and efficient in operation if a systematic study in circulation analysis is made for the operating boiler and identification of desired circulation ratio is done.

The circulation analysis needs to be conducted for water tube boiler under various failure modes to evaluate the robustness of the design of the boiler. The average circulation ratio is estimated during the design stage and followed thereby to ensure safe and efficient operation of the boiler.

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