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## Design of Reheater for Superheated Steam in Water Tube Boiler

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**ABSTRACT:** Boiler, also known as steam generator, is a closed vessel in which water is converted into steam above the atmospheric pressure by the application of heat. The steam generating unit is defined as "A combination of apparatus for producing, recovering heat together with the apparatus for transferring the heat. A water tube boiler is a type of boiler in which water circulates in tubes heated externally by the fire. Fuel is burned inside the furnace creating hot gases which heats water in the steam generating tubes. In this project water tube boiler is kept under study and problem of steam venting is identified. A system is to be developed in order to avoid the situation by heating the steam externally. 33 tone/ hour capacity water tube boiler is kept under study. As per the design 24 tone/hour saturated steam and 9 tone/hour superheated steam is produced. The pressure conditions are 25 bar and 19 bar respectively. The temperature of saturated steam is 225°C and superheated steam is 330°C. The correct temperature of superheated steam is maintained only when the load conditions (24:9) are satisfied. When the demand of saturated steam is reduced superheated steam doesn't get correct temperature. Presently in this situation in order to maintain correct temperature of superheated steam some quantity of saturated steam is vented out. When this situation occurs temperature of superheated steam is reduced to 250°C. Average 4 to 5 tone steam is vented in an hour. Cost of steam is around Rs3500/ tone, In order to avoid the situation of steam venting and to attain the proper temperature of superheated steam a reheater for superheated steam is designed and it is analyzed using ANSYS software. Also study about boilers is conducted. From the ANSYS analysis get the output temperature of steam is 340°C, which satisfies our demand. And from the cost estimation it is proved that the system is economical.

**KEYWORDS:** Text detection, Boiler, Reheater, Design, superheated steam

### I. INTRODUCTION

Boiler, is a closed vessel in which water is converted into steam by the application of heat. The steam generating unit is defined as "A combination of apparatus for producing, recovering heat together with the apparatus for transferring the heat. By the middle of eighteenth century boilers were invented. The first boilers were capable of producing steam at a constant low pressure over a considerable period of time and with minimum amount of attention and the engines which used steam could operate at constant speed performing useful work. In those days the designers were confronted with difficulty of obtaining suitable materi. Concurrent with the introduction of steam machinery, coal mining, which until then had been of low production came to the fore, and coal quickly became the fuel for the manufacture of iron and for steam production.

Boilers in those days were designed for low pressure and were often of very peculiar shape to meet various local conditions. It soon became apparent, however that circular form was the best for resisting internal pressure, and the ever increasing demand for steam in factories led to the development of large tank boilers, fired externally, with flue gases away to tall chimney at high temperature. Later the need for quickly raising of steam, increased power and decreased weight focused their attention on water tube boilers for steam production. Boilers can be classified into

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different types on the basis of different categories. According to flow of water and hot gases boilers classified into fire tube and water tube boiler. In this project the water tube boiler is kept under study.

33 tone/ hour capacity water tube boiler is kept under study. As per the design 24 tone/hour saturated steam and 9 tone/hour superheated steam is produced. The pressure conditions are 25 bar and 19 bar respectively. The temperature of saturated steam is 225°C and superheated steam is 330°C. The correct temperature of superheated steam is maintained only when the load conditions (24:9) are satisfied. When the demand of saturated steam is reduced superheated steam doesn't get correct temperature. Presently in this situation in order to maintain correct temperature of superheated steam some quantity of saturated steam is vented out. When this situation occurs temperature of superheated steam is reduced to 250°C. Average 4 to 5 tone steam is vented in an hour. Cost of steam is around Rs3500/ tone.

In this project in order to avoid the problem of steam venting and to ensure the correct temperature of superheated steam a reheater for superheated steam is designed and it is analyzed using ANSYS software. Running cost estimation is done in order to check whether the system is economical or not.

The work in this paper is divided in two stages. 1) Design of reheater 2) analysis of reheater

## II. RELATED WORK

Earlier there are some works are done to improve the efficiency of boiler. Sometimes heat exchngers are used to improve the efficiency. And also works are done to improve the life time of boiler parts.some works are also done to prevent the heat losses in boilers. There are some modification and analysis works done on water tube boilers.

The below shown figures are schematic representation of fire tube and water tube boilers

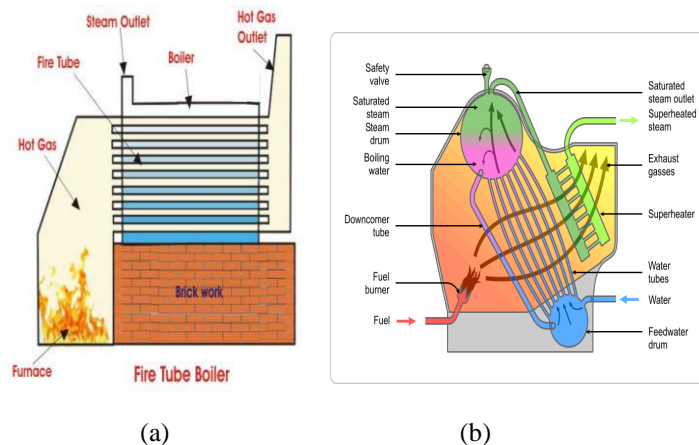


Fig. 1. Type of boilers (a) Fire tube boiler (b) Water tube boiler

## III. PROBLEM BACKGROUND

33 tone/ hour capacity water tube boiler under study. As per the design 24 tone/hour saturated steam and 9 tone/hour superheated steam is produced. The pressure conditions are 25 bar and 19 bar respectively. The temperature of saturated steam is 225°C and superheated steam is 330°C. The correct temperature of superheated steam is maintained only when the load conditions (24:9) are satisfied. When the demand of saturated steam is reduced superheated steam doesn't get correct temperature. Presently in this situation in order to maintain correct temperature of superheated

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steam some quantity of saturated steam is vented out. When this situation occurs temperature of superheated steam is reduced to 250°C .Average 4 to 5 tone steam is vented in an hour. Cost of steam is around RS 3500/ ton.

## IV. EXPERIMENTAL RESULTS

The thermal, chemical and physical properties of material are considered and suitable material for the tubes is selected. By considering the thermal properties we are selecting T11 material as the material for our tube. T11 material is commonly used for the super-heated coils. T11 is the material used in the super-heated coils in the boiler under study.

Table 1 describes about properties of T11 material like tensile strength, yield strength, elongation etc.

Table 1 Properties of material

Tensile strength(min)	415Mpa
Yield strength(min)	220Mpa
Elongation	30%
Delivery condition	annealed

Table 2 describes about the chemical compositions of T11 material.

Table 2Chemical compositions

Carbon	0.05–0.15
Manganese	0.30–0.60
Phosphorus	0.025
Sulphur	0.025
Silicon	0.50–1.00
Nickel	...
Chromium	1.00–1.50
Molybdenum	0.44–0.65
Vanadium	...
Boron	...
Niobium	...

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Some physical properties  
Thermal conductivity : 33 w/mk  
Specific thermal capacity : 622 j/kg k  
Density : 7.76 kg/dm<sup>3</sup>

## V. DESIGN OF REHEATER FOR SUPERHEATED STEAM IN WATER TUBE BOILER

In order to avoid the condition of steam venting, maintain the accurate temperature of superheated steam and to avoid the loss due to steam venting the reheater is designed. The calculations are shown below

Specific enthalpy of superheated steam at 250°C of 19 bar pressure is 2906.7 KJ/Kg

Specific enthalpy of superheated steam at 330°C of 19 bar pressure is 3084.3 KJ/kg

Energy needed to increase the temperature from 250°C to 330°C = 177.6KJ/kg

Energy needed for 9 tone is 1598400 KJ

Fuel used

We are using LPG as fuel in this system. The reasons for using LPG are less time for start-up, availability, no pre heating is required, and quantity of air required is lower than that of other fuels. Calorific value of LPG is 46.1\*10<sup>3</sup> KJ/Kg.

The amount of fuel required to generate 1598400KJ energy =  $1598400 / 46.1 \times 10^3$   
= 34.672 kg

The amount of fuel required to generate 1598400 kJ is 34.672 kg

Air fuel ratio of LPG by mass = 15.5:1  
Mass of air = 34.672\* 15.5  
=537.416

The equation used K =  $\frac{QL}{A\Delta T}$

Where K conductivity

Q energy needed in one second

L length of heat transfer

A area

$\Delta T$  change in temperature in kelvin

The  $\Delta T$  is calculated from energy balance equation

Q= mcp $\Delta t$

As per the existing boiler condition the temperature difference ( $\Delta t$ ) between

Steam and flue gas is 300°C

By using this  $\Delta t$  we can find out the rate of heat addition

Energy needed per second = 1598400/3600

= 444KJ/s

444 = m cp $\Delta t$ \*rate of heat addition

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$$M = 537.416/3600$$

$$= 0.14928$$

$$C_p = 1.005$$

$$\Delta t = 300^\circ\text{C}$$

Then rate of heat addition  $= 9.864$

Then by equating the energy balance equation

$$537.416 * 1.005 * 9.8 * \Delta t = 9000 * 2.27 * 80$$

Then  $\Delta t = 300$

From the conductivity equation we are getting Area  $= 134.54 \text{ m}^2$

From the equation of area of tube we get total length of the tube  $= 1070.635 \text{ m}$

(Total length of the furnace is assumed as 3m)

The total number of tubes  $= 1070.635/3$

$$= 356$$

### Design of tubes

The thickness of boiler tubes can be calculated as per Indian boiler regulation. The outside diameter tube is taken as 40mm, because the outside diameter of superheated coil used in the corresponding boiler is 40mm.

The thickness of tubes can be determined by the following formula  $W.P = 2f(T-C)/(D-T+C)$

W.P=working pressure

$C = 0.75 \text{ mm}$  for working pressure up to  $70 \text{ kg/cm}^2$

$C = 0$  for working pressure exceeding  $70 \text{ kg/cm}^2$  T minimum thickness of tube

The f can be determined by following

- a) For integral economiser tubes, the maximum temperature for which part of the element is designed plus  $11^\circ\text{C}$
- b) for furnace and boiler tubes, the saturation temperature corresponding to the working pressure plus  $28^\circ\text{C}$
- c) For convection super heater tubes, the maximum steam temperature for which the part of the element is designed plus  $39^\circ\text{C}$
- d) For radiant super heater tubes the designed maximum steam temperature plus 50

As per Indian boiler regulation 338(b) in no case shall the thickness of tubes as supplied be less than those given in the table 3

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Table 3 Indian boiler regulation 338(b)

Outside diameter	Seamless hot finished	Seamless cold drawn or electric resistance welded
Up to and including 32mm	2.9mm	2.03mm
Up to and including 51mm	3.25mm	2.34mm
Over 51mm up to and including 76mm	3.35mm	2.64mm
Over 76mm up to and including 89mm	3.25mm	3.25mm
Over 89mm up to and including 114mm	3.66mm	3.66mm

By calculating the thickness of tube as per the equation we get only 1.77mm, as per the above table this is not acceptable. As per the table there should be minimum thickness of 3.25mm. Then for the standard size of tube we take thickness of tube as 4mm.

Then, outer diameter of tube = 40mm  
Inner diameter of tube = 36mm

Volume of tube =  $3.14 * r^2 * h$

= 3769.91 m<sup>3</sup>

For 365 tubes = 1342088.382 cm<sup>3</sup>

Air fuel ratio of LPG by mass = 15.5:1

Mass of air = 34.672 \* 15.5

= 537.416

Total volume of air = mass of air / density

= 537.416 / 1.225

= 438.706 m<sup>3</sup>

Volume of air / second = 121862.7778 cm<sup>3</sup>/s

Difference in volume due to temperature change =  $\frac{v1}{T1} = \frac{v2}{T2}$

T1 = 29°C

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$$T_2 = 770^\circ\text{C} \quad (\text{existing condition of flue gas inlet})$$

$$V_2 = 3127811\text{cm}^3$$

Volume of furnace = volume of tube + volume of air/second

$$= 4469899\text{cm}^3$$

(Length and breadth of furnace is taken as 3m and 2.5

Width of the furnace = 59.59 cm

Wall thickness of furnace

The wall of the furnace is to be covered by the refractory brick. The minimum thickness of wall is to be calculated by the equation

$$K = \frac{QL}{A\Delta T}$$

$$K = 3\text{w/mk} \quad (\text{thermal conductivity of refractory brick})$$

$$Q = 444000\text{J/S}$$

$$A = 21.6\text{m}^2$$

$$\Delta t = 740 \quad (\text{difference between flue gas temperature atmospheric temperatures})$$

$$L = 0.108\text{m}$$

$$= 10.8\text{cm}$$

The below shown diagram represents the CATIA drawing of reheater designed.



Fig CATIA drawing of reheater

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The below shown diagram represents the position of reheater in the flow diagram of boiler under study.

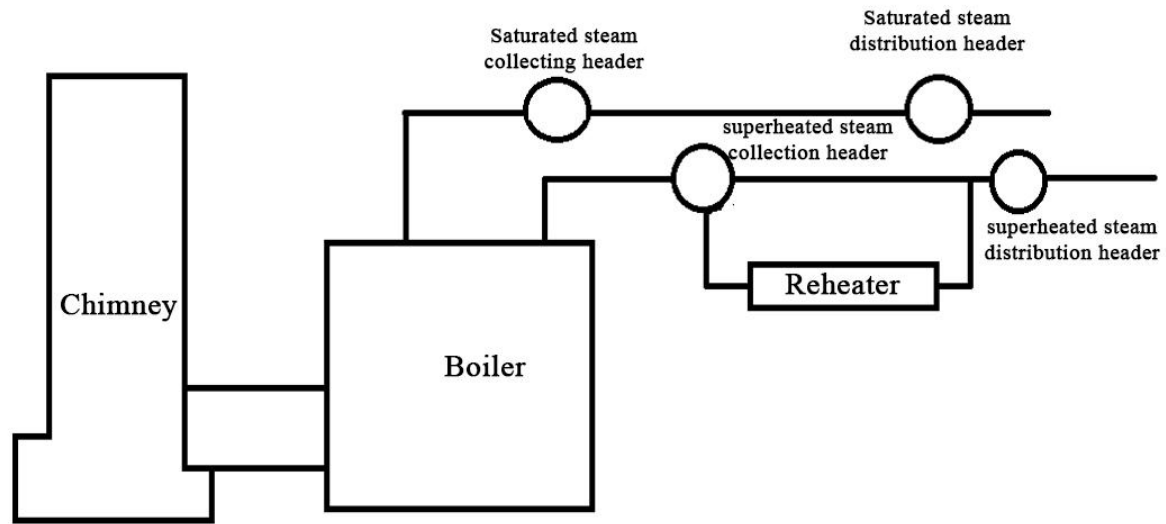


Fig schematic representation of position of reheater

## VI. CONCLUSIONS

- Detail study about the boiler is conducted
- Problem of steam venting is identified in water tube boiler under study
- Reheater for superheated steam is designed

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