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*Research Article*

# Comparative Analysis of an Evaporator Tube with and without Fins

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***Abstract***

*The current research paper summarizes the work carried out by authors on an evaporator tube. The work includes design, fabrication and testing of an evaporator tube in two variants; finned and un-finned versions. The outcome of the research is that, the finned version of the evaporator generates more steam when compared to the un-finned version without increasing the cost of material and space requirements.*

***Keywords:*** *Steam, fins, heat transfer rate, surface area, welding, evaporator, quality.*

## 1. Introduction

Water tube boiler consist of longitudinal drum connected in a series of inclined tubes which are used as economizer, flue gases that are burnt in the combustion chamber are important for improving output of evaporator. Finned tubes with continuous rib or longitudinal fins are used, depending on the operating parameters of the working medium and the flue gas can be used for: heaters, economizers or super heaters, a feed valve is provided to fill the evaporator drum and inclined tubes with water, continuous flow of water is provided with feed pump through feed valve inlet. Safety valve is provided to prevent over pressure which could cause damage, rupture or collapse of the equipment, the level of water is indicated by level gauge. Finned pipe evaporator in boiler has fins which are welded on the drum and tubes of the evaporator with arc welding, surface area gets increased by finning on the surface, and fins are welded parallel to the direction of the flue gases, further improving heat transfer efficiency more than the round pipes or tubes. The heat transfer rate increase with the amount of contact area between the surface walls of tube with fluid. As to improve efficiency of the heat transfer rate to surface area fins can be used as an innovative in industry, materials required for fin are used accordingly to the amount of temperature and pressure to which it with stands the flue gases, fins can be used in evaporators, economizers, super heaters, fins can be easy to manufacture and also cost low compared to extending the evaporator chamber which greatly leads to reduction in space and investment, any mechanical errors occurred during the manufacturing area also rectified easily and repaired thus making finned tube evaporator more efficient and economical for steam generation. This type of boilers can be used for decentralized power generation in many places.

## 2. Methodology

In this experimental research water tube boiler with considerably small in size is undertaken. Which is been fabricated and designed with required calculation. Low Carbon steel material is used for fabricating evaporator. The properties of the metal that are been used in this setup are been listed below in Table 1.

**Table 1** Material properties

| Elements | contents |
|---|---|
| Carbon | 0.14-0.20% |
| Iron | 98.81-99.26% |
| Manganese | 0.60-0.90% |

The fins that are been used also made of low carbon steel material and has same properties which works effectively in heat absorption.

The methodology undergoes the amount of flue gases that are been generated in the combustion chamber, flue gases are formed by opening the fire gate and burning of bio fuels inside combustion chamber. Bio fuels which are also renewable energy is used in the combustion as this leads to good combustion rate and easy mode of getting high temperature flue gases. The flue gases are directed towards the evaporator tube which further absorbs the heat from the flue gases, as the temperature rises from sensible heat to latent heat (>100°C). start generating steam inside the tube, the temperature increases gradually as the pressure reaches to >2bar the steam is further sent to super heater where it gets superheated heat and gives a pure form of steam as an output.

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Pressure of 2bar is taken into consideration as this is an experimental setup, as it is restricted to only 2bar which is controlled by safety valve which ejects the excess steam out. Further it can be increased to 10 bar with an ease. As it can with stand that pressure. And temperature of >500°C.

## 3. Fabrication

### *3.1. Material Employed*

In this experiment setup involves the major component i.e. Evaporator chamber which has a hallow cylinder of length 700mm and a thickness of 13mm low carbon steel which is highly durable and can with stand certain temperature's, nozzles are made of carbon steel and have less thickness as they server different purpose and does not need those high thickness. Fins are of low carbon steel material with a thickness of 3mm.

### *3.2 Fabrication process*

Fabrication carried out is done with arc welding which is effectively resistant to the heat that is produced during the experiment. Combustion chamber, evaporator and super heater parts ducting is made with 3mm thick low carbon steel metal. Evaporator tube with holes drilled on it at regular distances as shown in figure 1. And are used for equipping gauges, feed water pump, water level indicator, and steam output nozzle. Nozzle is welded on the top for steam output which is further connected to super heater as shown in figure 2. T bar is used to connect the super heater pipes and also a safety valve on it. Fins are welded on the surface of the evaporator tube with an angle of 45˚ respectively from the center and 90˚ angle with other fin total 4 fins are used as this surface area of four fins are enough according to our design as shown in figure 3.

There are 4 legs provided to fix the evaporator in place with duct cover in high boiling conditions it will remain stable and minimize errors as show in in figure 4. Super heater connected gets a damper which is an additional to escape tube failures at higher temperatures. Temperature gauges are placed at the team outlet of evaporator chamber and also at super heater chamber to continuously monitor the temperature difference, pressure gauge is placed on evaporator tube to note pressure rise in that tube.

**Figure 1** Evaporator tube with holes

**Figure 2** Evaporator tube with nozzle

**Figure 3** Evaporator tube with fins

**Figure 4** Evaporator tube in ducting

## 4. Equations

**Table 2** Experimental equations

| Title | Equation |
|---|---|
| Area of circle | $A = \pi r^2$ |
| Cylinder area | $2 \times \pi \times r \times l$ |
| Fin area | $A \times 2$ |
| Heat to be supplied to evaporator | $Q=(\lambda_1-\lambda_2)\times W$ |
| Initial temperature difference | $TFi - T$ |
| Terminal temperature difference | $TFo - T$ |
| Overall heat transfer coefficient | $U1 \times FW \times FM \times FC$ |
| Total area required | $\frac{Q}{(U \times (TFo - T1))}$ |
| Tube area | $(2 \times \pi \times r \times l) + (\pi \times r^2)$ |
| Heat to be supplied with fins | $U \times \pi D \times A$ |
| Steam generated | $\frac{Q}{\lambda 1 - \lambda 2}$ |
| Design margin consideration | $\frac{A}{(1 - A5)} \times 100$ |

## 5. Schematic Layout

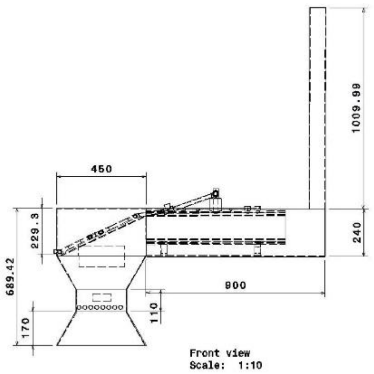



**Figure 5** Experimental boiler layout (Front view)

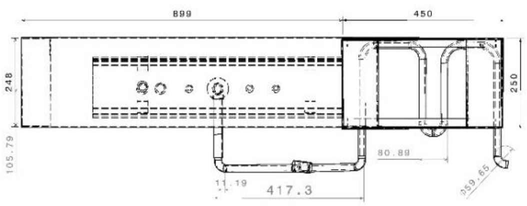



**Figure 6** Experimental boiler layout (bottom view)

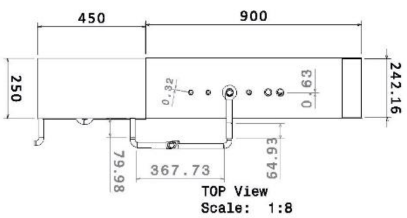



**Figure 7** Experimental boiler layout (Top view)

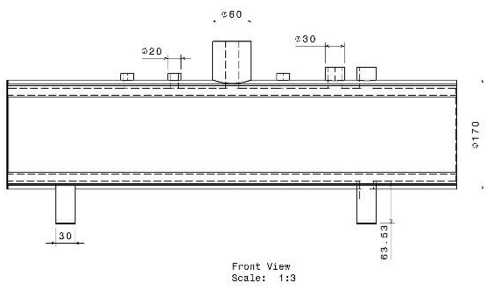



**Figure 8** Experimental evaporator layout (Front view)

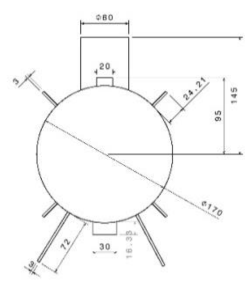



**Figure 9** Experimental evaporator layout (Side view)

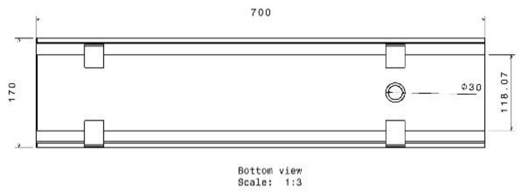



**Figure 10** Experimental evaporator layout (Bottom view)

## 6. Values

Values that are obtained after testing evaporator with temperature gauges and pressure gauge.

**Table 3** Tested value

| Temperature gauge 1 ˚ C | Temperature gauge 2 ˚ C | Pressure gauge |
|---|---|---|
| 100 | 90 | 0 |
| 110 | 95 | 1 |
| 112 | 96 | 1.1 |
| 114 | 106 | 1.2 |
| 120 | 110 | 1.5 |
| 122 | 115 | 1.6 |
| 130 | 118 | 1.8 |
| 138 | 120 | 1.9 |
| 139 | 130 | 2.0 |

## 7. Evaporator Tube value

**Table 4** Terminology and values.

| Symbol | Name | Values |
|---|---|---|
| Ts | Feed water inlet temperature | 100°C |
| λ1 | Steam Enthalpy | 647.44019kcal/kg |
| λ2 | Hot water enthalpy | 100.2870kcal/kg |
| T1 | Steam outlet temperature | 130°C |
| T2 | Hot water inlet temperature | 100°C |
| Tr | Temperature rise due to steam phase direct heating | 30°C |
| Tfi | Flue gas inlet temperature | 300°C |
| Tfo | Flue gas outlet temperature | 180°C |
| ITD | Initial temperature difference | 200°C |
| TTD | Terminal temperature difference | 50°C |
| U1 | Uncorrected heat transfer coefficient(HEI) | 1674.873086kcal/ $m^2h$°C |
| FW | Inlet water correction factor(HEI) | 0.823kcal/$m^2h$°C |
| FM | Tube material and gauge correction factor(HEI) | 1.1283kcal/$m^2h$°C |
| FC | Cleanliness factor(HEI) | 0.6528 kcal/$m^2h$°C |
| D | Tube outer diameter | 170mm |
| D1 | Tube inside diameter | 144mm |
| L | Length of the tube considered | 700mm |
| A | Area considered | 0.40$m^2$ |
| DM | Design margin consideration | 5.0641% |
| W1 | Water quantity | 15 lts |
| T | time | 30 mts |

## 8. Calculations

*8.1. without fins*

Cylinder plate area:

$A_1 = \pi \times 0.085^2$
$A_1 = 0.22698\ m^2$

Cylinder Area:

$A_2 = 2 \times \pi \times r \times l$
$A_2 = 2 \times \pi \times 0.085 \times 0.7$
$A = 0.373\ m^2$

Fins Area:

$A_3 = A \times 2$
$A_3 = 0.7 \times 0.05 \times 2$
$A_3 = 0.07 m^2$

Total Fins:

$A_4 = A_3 \times 4$
$A_4 = 0.07 \times 4$
$A_4 = 0.28 m^2$

Heat to be supplied for evaporator:

$Q = (\lambda 1 - \lambda 2) \times W$
$Q = (647.440 - 100.287) \times 35$
Q=19150.358Kcal/kg.

Steam generated without fins:

$= \frac{Q}{\lambda_1 - \lambda_2}$
$= \frac{19150.358}{647-100}$
=35.00kg/hr.

Initial temperature difference:

$T_{fi} - T_2$
= (300-100)
= 200°C

Terminal temperature difference:

$T_{fo} - T_1$
= 180-130
= 50°C

Overall heat transfer co-efficient (U):

$= U_1 \times FW \times FM \times F$
$= 1674.873 \times 0.823 \times 1.1283 \times 0.6528$
= 1015.2815 kcal/m²h°C

Total area required ($A_5$):

$\frac{Q}{(U \times (T_{Fo} - T_1))}$
$= \frac{19150.358}{(1015.28 \times 50.00)}$
$A_5 = 0.38 m^2$

Area considered (A):

$A_6 = (2 \times \pi \times r \times l) + (\pi \times (r)^2)$
$A_6 = (2 \times \pi \times 0.085 \times 0.7) + (\pi \times (0.085)^2)$
$A_6 = 0.40\ m^2$

Design margin considerations:

$\frac{A}{(1 - A_5)} \times 100$
$= \frac{0.40}{1 - 0.38} \times 100$
= 64.51kg/hr.

*8.2. with fins:*

Area:

$A = A_1 + A_2 + A_4$
$A = 0.373 + 0.022 + 0.28$
$A = 0.672\ m^2$

Heat to be supplied to evaporator (Q):

$U \times \pi D \times A$
= 1015.28×50.00×0.672
= 34113.45 K.cal

Steam generated with fins:

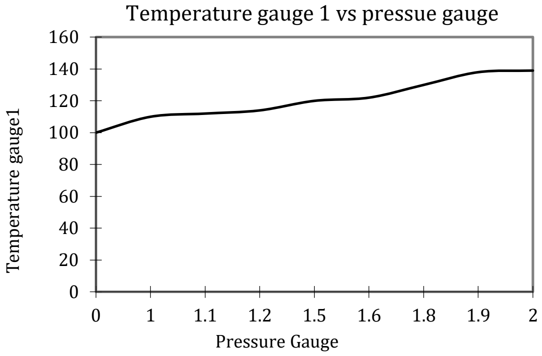
$\frac{Q}{\lambda_1 - \lambda_2}$
$= \frac{34113.45}{647-100}$
= 62.347 kg/hr.

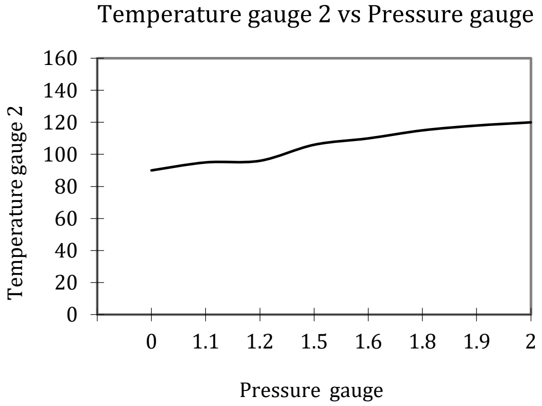
## 9. Final Result

**Table 5** Different Values obtained

| S.No | Type of evaporator | Value |
|---|---|---|
| 1 | Steam output in Evaporator without fins | 35kg/hr. |
| 2 | Steam output in Evaporator with fins | 62.347kg/hr. |

## 10. Graphs




## Conclusion

The above experiment shows how fins play a major role in heat transfer rate, as the surface area is directly proportional to heat transfer rate steam generation without fin or in circular tube is 35kg/hr at 2bar pressure, by adding fins to the same evaporator tube steam of 62.347 kg/hr at 2bar pressure is generated. Keeping the length of the evaporator tube constant i.e.700mm. The main advantage of fins are to absorb maximum heat from the flue gases that are produced in combustion chamber, Addition of fins in evaporator tube decreases material cost and space in small and medium scale industries.

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