An Experimental investigation of Gas Geyser’s Heat Exchanger with addition of Economizer

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ABSTRACT
Water heating can be attributed as the second largest energy use in the homes and can account for nearly a quarter of overall household energy consumption. Home residents depend on a reliable and sufficient supply of hot water for multiple uses in the home, and they are increasingly aware of the energy and carbon implications of different hot water systems. Rising energy prices and other economic pressures have created more interest in energy efficient hot water systems which reduce monthly expenses and at same time provide reliability and comfort. Gas geysers are one such device, which are energy efficient and economical at same time.

In this research work basic idea is to analyse the change in amount of heat transfer and calculating overall efficiency of a gas water heater by making small changes in the design of the heat exchanger of a gas geyser. A small scale experiment was set up and conducted in Heat transfer lab at PCET, Lalru Mandi. Heat flow through a gas geyser was calculated firstly without use of economiser and then experiment was again performed with same variable after addition of the economisers, so as to calculate percent change in heat flow.

The calculations and results are integral part of the report; first chapter of the report is dedicated to introduction of gas geyser and its mechanism, followed by literature review. Third chapter is to define objectives of the study and experimental setup and result analysis complete this thesis report. In the end, based on the outcomes of experiment Percent change in amount of heat flow with addition of economiser is calculated as to be 25%.

Keywords – Gas Geyser, Heat Exchanger, Economiser, Heat Flow.

1. INTRODUCTION

1.1. Gas Geyser
Water heating can be attributed as the second largest energy use in the homes and can account for nearly a quarter of overall household energy consumption. Home residents depend on a reliable and sufficient supply of hot water for multiple uses in the home, and they are increasingly aware of the energy and carbon implications of different hot water systems [6]. Rising energy prices and other economic pressures have created more interest in energy efficient hot water systems which reduce monthly expenses and at same time provide reliability and comfort.

Moreover for people residing in areas which are prone to power outage electric water heaters are of lesser use. So, residents have to look for alternate products for the reasons stated above. Possible alternates which are used effectively are gas geysers and solar water heaters.

Tank less gas geysers can be thought of as one such water heating equipment which can be seen as solution to residents because of its many advantages over conventional electric water heater as it consumes lesser energy[1] has better flow rate[2] and lesser standby losses. The heating system of the gas geysers is based on a simple technology. The burning of LPG, ignited through an electric impulse created by the built-in batteries, heats up the pipeline through which water passes, and the water gets heated in the process. The burner flame as well as water pipeline are routed through the heat exchanger. As soon as the gas is ignited, burner flames heat up the heat exchanger pipes and the hot water is obtained from the water outlet. Since there is no provision for manual ignition of the Gas Geyser, the only source of initial ignition is through the commencement of water output flow where the ignition system automatically ignites the burner flames by electric impulse.

The heater has been in demand for its low operation costs as compared to electric heaters. But, with LPG prices touching the roof, the difference is not considerable anymore. However, at places where power outage is a problem, gas water heaters provide for a practical alternative. Although being an alternative solution for one problem, the gas water heater comes with a baggage – that of environmental as well as health hazard. A considerable amount of carbon monoxide (CO) is emitted by the heater into the air while burning the gas.
1.2 Principle of gas geyser

Gas geyser is based on the principle of convection. Convection \[^3\] is the mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. The faster the fluid motion, the greater the convection heat transfers. In the absence of any bulk fluid motion, heat transfer between a solid surface and the adjacent fluid is by pure conduction. The presence of bulk motion of the fluid enhances the heat transfer between the solid surface and the fluid, but it also complicates the determination of heat transfer rates. Consider the cooling of a hot block by blowing cool air over its top surface \[^3\].

Despite the complexity of convection, the rate of convection heat transfer is observed to be proportional to the temperature difference, and is conveniently expressed by Newton’s law of cooling as

\[
Q_{\text{conv}} = h A_s (T_s - T_f)
\]

Where \(Q\) is amount of heat transfer in watts, \(h\) is the convection heat transfer coefficient in \(\text{W/m}^2\degree\text{C}\), \(A_s\) is the surface area in \(\text{m}^2\) through which convection heat transfer takes place, \(T_s\) is the surface temperature in \(\degree\text{C}\), and \(T_f\) is the temperature of the fluid sufficiently far from the surface in \(\degree\text{C}\).

2. PROBLEM FORMULATION

It is revealed from literature review that no major research work has been done for the study of a gas geyser’s heat exchanger to analyse the heat flow by addition of economiser or by addition of extended surfaces.

2.1 Objectives of Study

1. To study the effect of addition of economizer on overall heat exchanger’s efficiency.
2. To analyse change in heat transfer rate with addition of economizer.

3. METHODOLOGY

Experimental readings of temperature inlet as well as outlet for both water and air are measured with help of thermometers fitted at respective inlets and outlets of gas geysers. Other important values such as internal and external diameters of copper tubes carrying water are calculated using Vernier calliper, overall length of copper tubes is calculated using measuring tape and metre scale. Various formulae’s\[^3\],\[^10\] and relations of heat transfer are utilised to arrive at result and calculate overall heat transfer rate such as-

**Overall heat transfer coefficient:**

\[
U_0 = \frac{1}{1/h_0 + r_0/k \ln \left[ r_0/r_i \right] + \left[ r_0/r_i \right] 1/h_i}
\]

Where \(h_0\) = heat transfer coefficient of air
\(h_i\) = heat transfer coefficient of water
\(r_0=\) outer radius of copper tube
\(r_i =\) inner radius of copper tube
\(k =\) thermal conductivity of copper
Rate of heat transfer between the two fluids

\[ Q = U_0 A_s \Delta T \]

Where \( U_0 \) = overall heat transfer coefficient

\( A_s \) = Surface area of copper tube

\( \Delta T \) = Log mean temp difference

\[ LMTD = \frac{\Delta T_A - \Delta T_B}{\ln \left( \frac{\Delta T_A}{\Delta T_B} \right)} \]

Where \( \Delta T_A \) is the temperature difference between the Air at inlet and outlet and \( \Delta T_B \) is the temperature difference between the Water at inlet and outlet

3.1 Experimental Setup

To calculate amount of heat flow without an economiser an experiment was conducted on a gas geyser in Heat Transfer lab at PCET, Lalru. A domestic gas geyser as depicted in diagram below was connected with LPG cylinder on one side at a constant gas flow. Inlet pipe for water was connected to water source and outlet water pipe was connected to a water bucket having volume in litres depicted on outer side of it. Two thermometers were installed at inlet and outlet to read temperature of cold water and hot water.

Fig. 3.1 Experimental setup of gas geyser

Gas geyser’s heat exchanger is made of copper tubes, which are used to carry cold water from inlet to the hot region of geyser where flue gases heat up the water and the copper tube supplies the same at outlet which is further connected to water bucket via hose pipe.

3.2 Experimental Procedure

Firstly the experiment was conducted without any modification on a standard gas geyser at constant gas flow rate and water flow rate. Values of inlet and outlet temperatures were noted for each repetition. Discharge of water was also calculated. The above said experiment was repeated for six times and observation table was made so as to calculate heat transfer rate and heat flow.

Further the calculations were done based on the experimental findings, using various formulae’s of convection as discussed in research methodology so as to ascertain rate of heat flow without addition of economiser. The results obtained from the setup are included in next chapter.

Next part of the setup was to install an economiser so as to understand the effect it has on the overall heat transfer rate of the gas geyser and is discussed overleaf.

3.3 Modifications carried out in initial setup

To calculate rate of heat flow with an economiser few modifications were done in the heat exchanger of the gas geyser. A copper tube having same specification as that of heat exchanger was procured from the market. Afterwards bends were done at suitable places on this tube as visible in diagram below.

Fig. 3.2 Economizer installed at top of gas geyser

The tube then was welded at top of the gas geyser and was connected to the copper tube carrying water from the gas geyser. The entire joints were welded properly so as to avoid any loss in water flow. The experiment as mentioned earlier was repeated again this time with addition of economiser in form of copper tube at top of the heat exchanger. Copper tube was installed in such a manner that it can utilise the flue gases coming out of the heat exchanger and exhausting to the surroundings and hence working as an economiser.

Experiment was conducted again with same gas flow and water flow rate as in case of initial setup, so as to bring homogeneity to the study. Six repetitions were done for the experiment. Temperatures were noted and calculations were done.

4. CALCULATIONS AND ANALYSIS

4.1. Phase I - Observation table for Cold v/s hot water at constant Velocity of 2m/sec and 36.2°c inlet temperature without economizer

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Time</th>
<th>Inlet temperature</th>
<th>Outlet temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20 sec</td>
<td>36.2°c</td>
<td>50.6°c</td>
</tr>
<tr>
<td>2</td>
<td>40 sec</td>
<td>36.2°c</td>
<td>51.1°c</td>
</tr>
</tbody>
</table>
3 60 sec 36.2°c 51.4°c
4 80 sec 36.2°c 51.2°c
5 100 sec 36.2°c 51.0°c
6 120 sec 36.2°c 51.2°c

### Table 4.2 Observation table-II

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Time</th>
<th>Inlet temperature</th>
<th>Outlet temperature</th>
</tr>
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<tbody>
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<td>54.1°c</td>
</tr>
<tr>
<td>4</td>
<td>80 sec</td>
<td>36.2°c</td>
<td>53.8°c</td>
</tr>
<tr>
<td>5</td>
<td>100 sec</td>
<td>36.2°c</td>
<td>54.2°c</td>
</tr>
<tr>
<td>6</td>
<td>120 sec</td>
<td>36.2°c</td>
<td>54.2°c</td>
</tr>
</tbody>
</table>

### Figure 4.1 Graph between inlet and outlet temperature of water without economizer

Now, observation table for Cold v/s hot water at constant flow of 2m/sec and 36.2°c inlet temperature with economizer.

### Table 4.2 Observation table-II

<table>
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<tr>
<td>6</td>
<td>120 sec</td>
<td>36.2°c</td>
<td>54.2°c</td>
</tr>
</tbody>
</table>

### Figure 4.2 Graph between inlet and outlet temperature of water with economiser

#### 4.2 Case I: Calculation of heat flow rate without economiser

**Geyser specifications**
- Inside diameter \( D_i = 0.007 \text{ m} \)
- Outside diameter \( D_o = 0.0095 \text{ m} \)
- Length of tube \( l = 2 \text{ m} \)

**Experimental findings**
- Temperature of cold water \( = 36.2°c \)
- Temperature of hot (outlet) water \( = 51.2°c \)
- Water flow \( = 7 \text{ ltrs in 90 sec} \)
- Discharge of water per second \( Q = 0.077 \times 10^{-3} \text{ m}^3/\text{sec} \)
- Now velocity of water \( U = Q/A = 2 \text{ m/sec} \)

**Properties of saturated water at 51.2°c**
- \( \rho = 987.4 \text{ kg/m}^3 \)
- \( \nu = 0.543 \times 10^{-6} \text{ m}^2/\text{sec} \)
- \( k = 646.2 \text{ W/mK} \)
- \( Pr = 3.478 \)

**Reynold’s No., R =\( \frac{U D_i}{\nu} = 25783 \)**

So, overall heat transfer coefficient \( \text{[3]} \)

\[
U_0 = \frac{1}{\frac{1}{h_o} + \frac{r_o/k}{\ln \left( \frac{r_o}{r_i} \right)} + \left( \frac{r_o}{r_i} \right)}
\]

\( U_0 = 28.98 \text{ W/m}^2\text{K} \)

Now, amount of heat transfer, \( Q = U_0 A \Delta T \)

For \( \Delta T \),

\[
LMTD = \frac{\Delta T_A - \Delta T_B}{\ln \left( \frac{\Delta T_A}{\Delta T_B} \right)} = 37.5°c
\]

**Therefore**, \( Q = 28.98 \times A \times 37.5 = 64.86 \text{ W} \)

#### 4.3 Case II: Calculation of heat flow rate with economiser

**Geyser specifications**
- Inside diameter \( D_i = 0.007 \text{ m} \)
- Outside diameter \( D_o = 0.0095 \text{ m} \)
- Length of tube \( l = 2.5 \text{ m} \)

**Experimental findings**
- Temperature of cold water \( = 36.2°c \)
- Temperature of hot (outlet) water \( = 54.2°c \)
- Water flow \( = 7 \text{ ltrs in 90 sec} \)

**Discharge of water per second \( Q = 0.077 \times 10^{-3} \text{ m}^3/\text{sec} \)**

Now velocity of water \( U = Q/A = 2 \text{ m/sec} \)

**Properties of saturated water at 54.2°c**
- \( \rho = 985.7 \text{ kg/m}^3 \)
- \( \nu = 0.518 \times 10^{-6} \text{ m}^2/\text{sec} \)
- \( k = 648.2 \text{ W/mK} \)
- \( Pr = 3.67 \)

**Reynold’s No., R =\( \frac{U D_i}{\nu} = 27027 \)**

We know \( N_u D = 0.023 (R)^{0.8} (Pr)^{0.4} = 128.03 \)

Hence convective heat coefficient of water, \( h_i = N_u D \cdot \frac{k}{D_i} \)

Now for Air \( h_0 \) (convective heat coefficient for hot air) \( = 30 \text{ W/m}^2\text{K} \)

So, overall heat transfer coefficient \( \text{[3]} \)

\[
U_0 = \frac{1}{\frac{1}{h_0} + \frac{r_o/k}{\ln \left( \frac{r_o}{r_i} \right)} + \left( \frac{r_o}{r_i} \right)}
\]

\( U_0 = 28.98 \text{ W/m}^2\text{K} \)

Now, amount of heat transfer, \( Q = U_0 A \Delta T \)

**For \( \Delta T \),**

\[
LMTD = \frac{\Delta T_A - \Delta T_B}{\ln \left( \frac{\Delta T_A}{\Delta T_B} \right)} = 37.5°c
\]

**Therefore**, \( Q = 28.98 \times A \times 37.5 = 64.86 \text{ W} \)
Now for Air, $h_0$ (convective heat coefficient for hot air) = 30 W/m²K
So, overall heat transfer coefficient,

$$U_0 = \frac{1}{h_0 + \frac{r_0}{k} \ln \left(\frac{r_0}{r_i}\right) + \frac{r_0}{r_i}}$$

$U_0 = 30.21$ W/m²K

Now, amount of heat transfer,

$$Q = U_0 A \Delta T$$

For $\Delta T$, LMTD

$$LMTD = \frac{\Delta T_A - \Delta T_B}{\ln \left(\frac{\Delta T_A}{\Delta T_B}\right)} = 40^\circ C$$

Now, $Q = 28.98 * A * 40 = 90.16$ W

4.4 Change in amount of heat flow

Percent Change in heat flow with and without economiser\[3\] = \(\frac{Q\text{with economizer} - Q}{Q\text{ with economizer}}\) *100

= \(\frac{90.16 - 64.86}{90.16}\) *100

= 28.07 %

5. CONCLUSIONS AND FUTURE SCOPE

Conclusion

The purpose of the experiment was to analyse the effect of economiser on overall efficiency of Gas Geysers. Experiment was conducted on a gas geyser with very minor changes in the design of the heat exchanger. Following point can be concluded from the research.

1. Economiser was successfully installed on the gas geyser and has resulted in higher outlet temperature, as the amount of heat flow has increased by 28 %, because of better utilisation of flue gases by economiser.

Future Scope

Scope of future investigation in heat exchanger is very vast. Further research can be conducted on heat exchanger to analyse the change in flow rate by

- Taking Heat exchanger pipes of different materials.
- Taking Heat exchanger pipes of different sizes.
- Furthermore, addition of extended surfaces (fins) on the heat exchangers can also be studied, as there is no or very little study being conducted in these areas.

REFERENCES